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Tomano Oil Spill in Casco Bay: Environmental Effects and Cleanup Operations

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This study was undertaken to determine the effects of No. 6 oil on marine communities of Casco Bay, Maine and to assess the effectiveness of containment and cleanup operations. Areas studied included rocky intertidal, intertidal mud, and sub-tidal benthic. Comparable control stations were chosen at Bailey Island and Orrs Island. Stations were analyzed for density and diversity of species as an indicator of stress. Sediments and selected biota were analyzed for No. 6 oil by gas chromatography. Results showed contamination at all stations, even those chosen as controls, indicating that the ultimate disposition of the oil did not correspond to sightings of surface slicks immediately following the spill.

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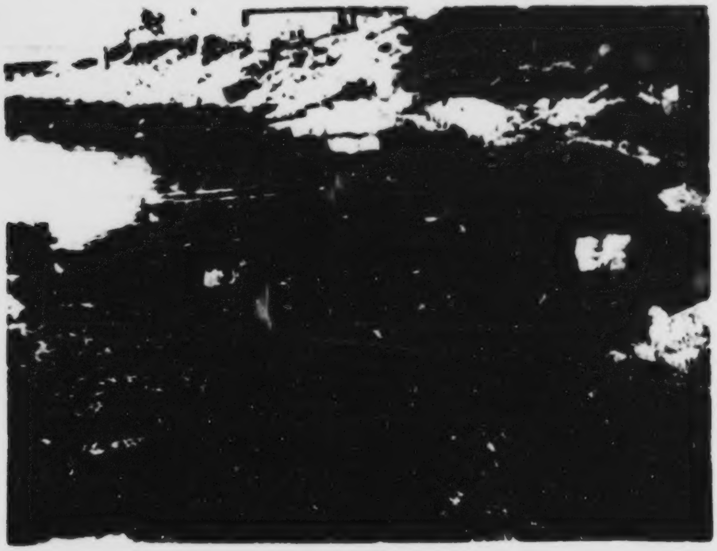

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF WATER PROGRAM OPERATIONS
WASHINGTON, D.C. 20460

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TOMANO OIL SPILL IN CASCO BAY: ENVIRONMENTAL EFFECTS AND CLEANUP OPERATIONS

By

Division of Oil and Special Materials Control
Office of Water Program Operations
U.S. Environmental Protection Agency
Washington, D.C. 20460

and

Region I
U.S. Environmental Protection Agency
Boston, Massachusetts 02194

December 1975

Under Contract
68-01-0542

FOREWORD

The primary objective of the Environmental Protection Agency's oil spill program is to protect water quality through the prevention of spills and by minimizing the environmental impact of those spills which do occur. The Tamano oil spill incident was selected for detailed investigation, both in the field and laboratory, to gain a better understanding of the interaction of oil with the various components of the hydrologic environment and to determine the effectiveness of counteracting the harmful effects of a spill. Results from such studies are intended to serve as the basis for establishing more comprehensive policies and procedures for the removal of oil from water in the most effective as well as least environmentally damaging manner.

This investigation was limited in scope and should not be compared to other studies which may have involved long-term research and considerably greater resources. The information contained in the report will hopefully provide government, industry, and the public useful information on short and long-term effects of No. 6 fuel oil on the marine communities of Casco Bay, Maine, and assess the effectiveness of cleanup operations. I want to express my sincere thanks and appreciation to everyone who participated in the successful completion of this comprehensive project.

H. D. Van Cleave
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Washington, D. C. 20460

EPA REVIEW NOTICE

This report has been reviewed by the Office of Water Programs, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ABSTRACT

This study was undertaken to determine the effects of No. 6 oil on marine communities of Casco Bay, Maine and to assess the effectiveness of containment and cleanup operations. Areas studied included rocky intertidal, intertidal mud, and sub-tidal benthic. Comparable control stations were chosen at Bailey Island and Orrs Island. Stations were analyzed for density and diversity of species as an indicator of stress. Sediments and selected biota were analyzed for No. 6 oil by gas chromatography. Results showed contamination at all stations, even those chosen as controls, indicating that the ultimate disposition of the oil did not correspond to sightings of surface slicks immediately following the spill. Species assemblages in Hussey Sound did not correspond with the control area, suggesting that chronic pollution in the Portland area has already caused a change in the species composition of infauna communities.

This report was submitted in fulfillment of Contract No. 68-10-0542, Order No. 001, under the sponsorship of the Division of Oil and Hazardous Materials, Office of Air and Water Programs, Environmental Protection Agency.

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SECTION I

CONCLUSIONS

1. The marine communities in the oiled areas were adversely affected to varying degrees. The relative order of disturbance ranging from most to least severe was:

    a. intertidal mud flats

    b. intertidal rocky areas, especially in the algae and barnacles

    c. sub-tidal benthic communities

2. Plants and animals in spill affected areas accumulated oil.

3. Delays in removing oil from beach sand on Long Island resulted in penetration of oil into the sand. Consequently, a six-inch layer of oiled sand had to be removed to prevent the beach from releasing oil back into the water.

4. Petroleum hydrocarbons were detected at 10 meters, indicating the ability of spilled oil to disperse to these depths.

5. Gull mortalities were higher than would be expected for non-spill conditions and a large percentage of the dead birds in the rookeries were oil-covered.

SECTION II

RECOMMENDATIONS

1. To evaluate the biological impact of an oil spill and the related cleanup operations, an initial survey should be conducted immediately after the spill, another one year later, and possibly another two years after the event.

2. Major oil ports should establish effective procedures for dealing with oil spills within their vicinity. Such procedures should include stockpiling the equipment necessary to contain and remove the oil and the logistical support required to transport this equipment to the spill. The capability for promptly off loading damaged or threatened vessels must also exist.

3. If oil ends up on the beaches, removal operations should be initiated as soon as possible to reduce penetration into the beach and leaching of oil back into the water.

4. The response of potential indicator organisms, such as amphipods, to various concentrations and types of oil should be identified along with variations in their natural habitat, so that they may be used as indicator organisms.

SECTION III

INTRODUCTION

The Accident:

At approximately 0120 EDT on July 22, 1972, the 810 ft Norwegian tanker Tamano, owned by Wilh Wilhelmsen of Oslo, Norway and under charter to Texaco, Inc., grazed Soldiers Ledge in Hussey Sound, Casco Bay, Maine, tearing a 20 ft by 8 ft hole near the turn of the bilge in the No. 1 starboard wing tank which contained approximately 12,000 barrels of No. 6 fuel oil of the low pour variety. The vessel, with a maximum draft of 58 ft registered a mean draft of 44 ft on approaching the Sound, where the Pilot's Association sets a maximum draft limitation of 55 ft. Soldiers Ledge lies at 40 ft (MLW), marked by a lighted buoy. The accident went unnoticed until 0200 when Tamano anchored in the Hussey Sound Anchorage, 2600 yards north of Long Island, Casco Bay, and oil was seen escaping from beneath the hull. The pilot immediately notified Sea Coast Ocean Services, a local cleanup contractor, and by 0530 booms were deployed from the bow to midships. U. S. Coast Guard (USCG) personnel arrived on scene at 0400 and by 0930, upon direction from the Coast Guard OnScene Coordinator (OSC), the ship was completely boomed. This action appeared adequate until 23 July, 1972, when Coast Guard overflights revealed that oil from beneath the Tamano hull was escaping to the surface beyond the booms. The OSC, in cooperation with Texaco, Inc., then called contractors from the Boston area for additional booms and skimmers. Auxiliary pumps were called in to assist Tamano in transferring oil from the damaged tank to other tanks, and skimmers commenced removing the oil from within the booms. The damaged tank was cleared of cargo by 25 July. Oil within the booms was removed and discharge of cargo was completed on 3 August, 1972. The Tamano cleared port for drydocking on 4 August, 1972. An initial report estimated the official loss of oil at 40,000 gallons. A later report stated that 100,000 gallons of oil escaped with 70,000 gallons of good oil being recovered. Due to the inaccuracies in estimating the amount of oil escaping into the environment or recovered in removal operations, the quantity of oil lost could be even greater than the reported 30,000 gallons.

Purpose of the Study:

This short-term (3-1/2 months) field study was undertaken for the purpose of providing the EPA with information and assessment in the following categories:

1. Effectiveness of oil spill control and cleanup measures taken immediately after the accident to keep the damage to the environment at a minimum;
2. Evidence of immediate and acute damage to the biota of the affected area and indications for long-range effects;
3. Data on the fate and effects of an oil spill in a specific location under specific conditions for use in the EPA's long-term program to develop an improved understanding of oil spills and their potential dangers under various conditions of weather, tidal currents and emergency response.

This survey was not intended as a comprehensive research effort on sublethal or long-term effects, such as the loss of reproductive capacity in survivors of the spill or rendering of the substrate unsuitable for the recruitment of young stages.

Movement of Oil:

During the first day (22 July), oil went ashore on the islands immediately surrounding the Tamano which was anchored midway between Long Island (C) and Clapboard Island (L), (See Figures 1 and 2). The waterborne oil was dispersed by tidal currents and by the second day (23 July), about 60% of Hussey Sound (M) was covered with heavy black streaks and rainbow films. The oil was still escaping from beneath the vessel. The affected area expanded northward to Cousins Island (N) and eastward to Cliff Island (O), while scattered pockets followed the non-tidal drift patterns southward from Spring Point (P) to Cape Elizabeth and Crescent Beach. By the third day (24 July), this southward drift had reached Prouts Neck near Old Orchard Beach (Figure 2).

During an overflight by VAST, Inc. personnel on 25 July (4th day), heavy concentrations were still very apparent within Hussey Sound, while lighter streaks and patches stretched southward and eastward, (Figure 2). There was little evidence of oil north of Cousins Island or Great Chebeague (Q). Six days after the spill (28 July), two large slicks still remained in the vicinity of the Tamano, extending towards Mackworth Island (R). Oil was still escaping from beneath the vessel. Crescent Beach to the south received another major slick. The southward movement continued to the beaches at

Cape Porpoise (Kennebunkport), and by 29 July the oil had reached Ogunquit. With the departure of the ship on 4 August, more oil escaped from beneath her hull. Several recovery operations were attempted with limited success. Much of the unrecovered oil washed ashore in the Long Island area.

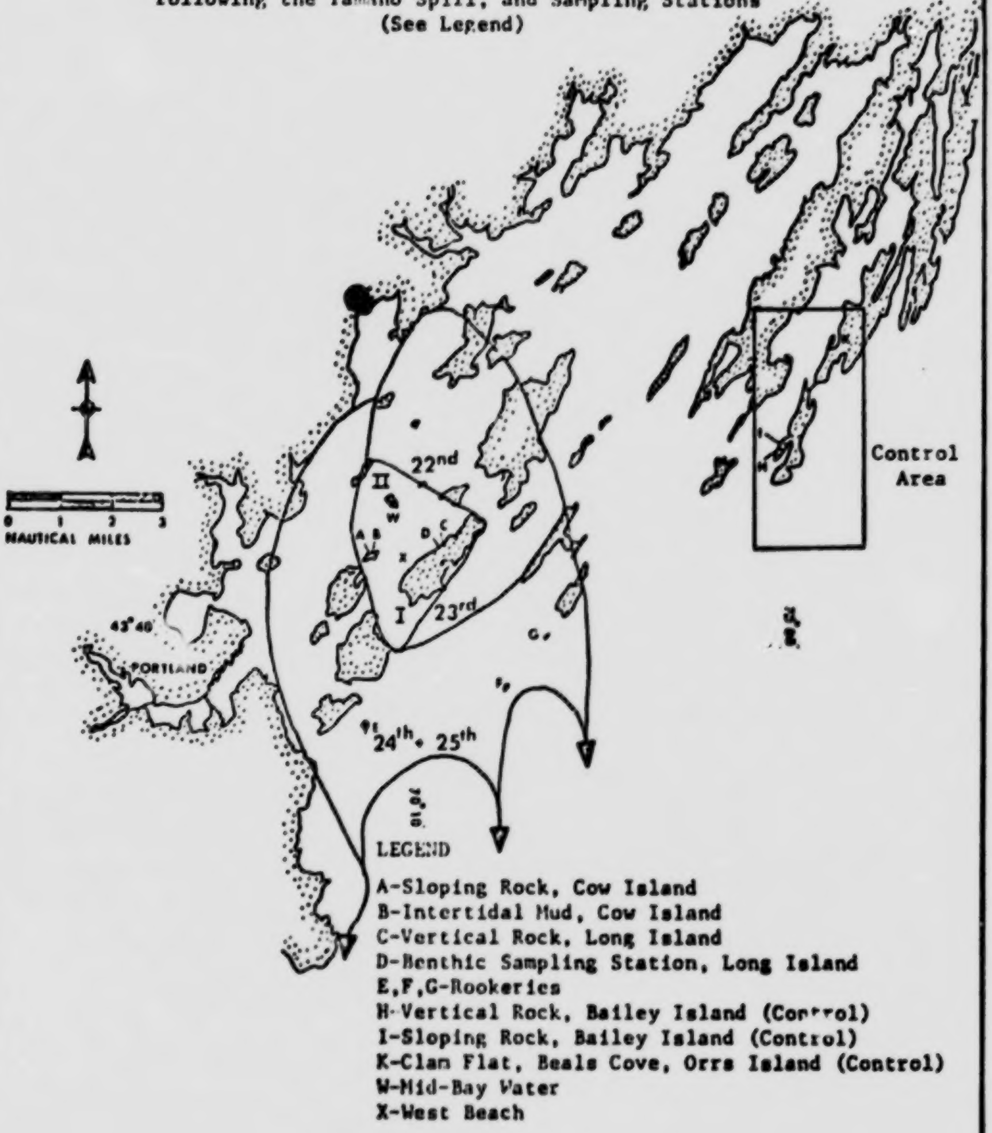
Thus, the pattern was one of concentric spreading of the oil outward from the moored vessel, which continued to be a source of fresh oil for fourteen days until she departed the area. In the absence of unusual weather conditions or strong winds, the oil was distributed by the tidal currents and the non-tidal drift currents. In all, the contamination included 46 miles of coastline from Falmouth to York, and 18 islands in Casco Bay (McCann, 1972).

Federal and Local Response:

The U. S. Coast Guard was the first governmental agency to be notified of the oil spill from the Tamano. At 0243 on 22 July, 1972, the Coast Guard was notified of the spill by the Portland Pilots. Coast Guard personnel were on the scene at 0400. Captain D. J. McCann, USCG, the predesignated On-Scene Coordinator (OSC), arrived at the Coast Guard Base, South Portland, to assume those duties at 0500, 22 July, 1972, after being notified of the spill at 0430, 22 July, 1972. The necessary action was taken on 22 July to activate the RRT in accordance with the National and Regional Contingency Plans and to alert federal, state and local agencies, including representatives of the Environmental Protection Agency, Region I, who were notified at 0600, 22 July, 1972. The Coast Guard Atlantic Strike Force was also notified. The OSC made two helicopter overflights, one at 0815 and the second at 1600 on 22 July, 1972. The OSC ordered additional booming as a result of the 0815 helicopter inspection and the additional booming was in place by 0930 on 22 July, 1972. The EPA Region I representatives arrived on the scene on July 22, 1972. The EPA and USCG representatives boarded the Tamano and sampled the contents of the holed tank. The OSC overflew the area again on 23 July, 1972, and noted that the situation had changed and that oil was swept under the boom by the current and tidal action. The OSC ordered two additional contractors from Boston to supplement the equipment of the local contractor. The OSC notified the ship's agents and Texaco of these actions. The OSC held a meeting on 23 July, 1972, with all interested parties to formulate plans for cleanup operations. The OSC instituted a 24-hour USCG watch onboard the Tamano and requested that a "Notice To Mariners" be issued to warn all vessels from entering an area one mile in radius

FIGURE 1

Casco Bay
Location of the Accident (I). The Tamano at Anchor (II), Movement of Oil Slicks within Casco Bay during the First Three Days following the Tamano Spill, and Sampling Stations
(See Legend)

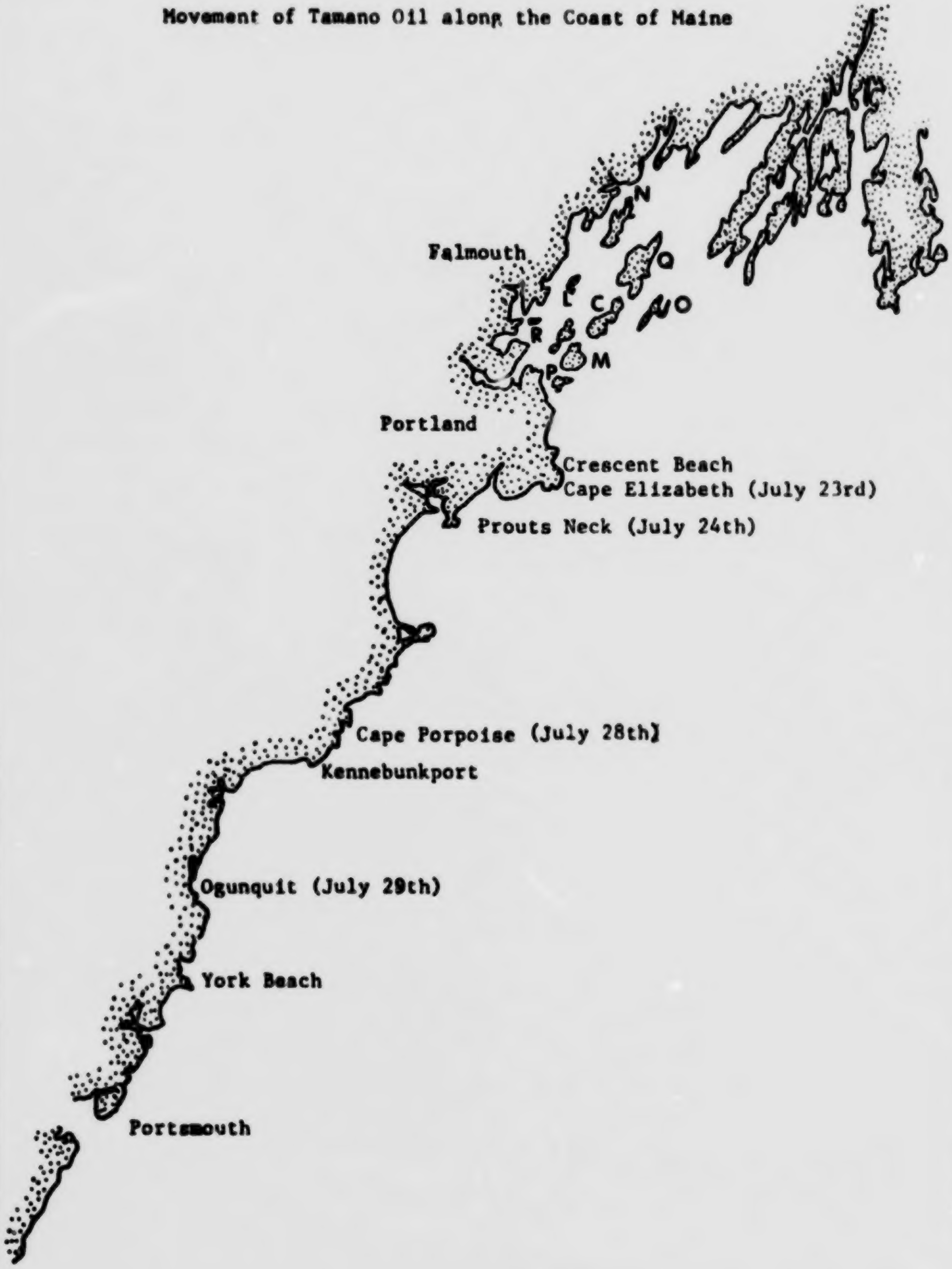


22nd
23rd
24th + 25th
II
I
A B
W
D C
X
G
H
I
Control Area
0 1 2 3
NAUTICAL MILES
43°40'
PORTLAND

LEGEND
A-Sloping Rock, Cow Island
B-Intertidal Mud, Cow Island
C-Vertical Rock, Long Island
D-Benthic Sampling Station, Long Island
E,F,G-Rookeries
H-Vertical Rock, Bailey Island (Control)
I-Sloping Rock, Bailey Island (Control)
K-Clam Flat, Beals Cove, Orrs Island (Control)
W-Mid-Bay Water
X-West Beach

FIGURE 2

Movement of Tamano Oil along the Coast of Maine


N
Falmouth
Q
C
O
L
R
M
P
Portland
Crescent Beach
Cape Elizabeth (July 23rd)
Prouts Neck (July 24th)
Cape Porpoise (July 28th)
Kennebunkport
Ogunquit (July 29th)
York Beach
Portsmouth

from position 43-42-33N, 70-10-23W, and including a warning for mariners to be on the lookout for oil booms and equipment in Hussey Sound. On 24 July, 1972, an overflight of the area was made by OSC and EPA representatives. Conferences were scheduled with the OSC, EPA and cleanup contractors and Texaco to review and coordinate the cleanup operations. On 25 July, 1972, further joint coordination and evaluation meetings and overflights were conducted by the OSC and the EPA representatives. The EPA contracted with VAST, Inc., on 25 July, 1972. Meetings to coordinate the cleanup and overflights were made, as required. On 1 August, 1972, the Corps of Engineers, U. S. Army, commenced a sonar sweep of Hussey Sound to check for uncharted hazards to navigation. The EPA, together with the Maine Sea and Shore Fisheries and the Maine Environmental Protection Department, conducted a joint survey on 1 August, 1972. The Maine Department of Inland Game conducted surveys on the 24, 25, 27, 28 and 31st of July, 1972. On 3 August, 1972, the Corps of Engineers, U. S. Army, reported to the OSC the sweep of Hussey Sound was complete and that no uncharted obstacles were located.

The EPA conducted surveys between 1 August and 17 August, 1972, and submitted written recommendations for cleanup procedures to the OSC on 17 August, 1972. These recommendations for cleanup were forwarded to the representatives of the ship's owners on 18 August, 1972, by the OSC. The EPA representatives observed oil from West Beach, Long Island, leaching back to the water column on 24 August, 1972, and recommended to the OSC that sand removal operations begin immediately. On 29 August, 1972, the OSC notified the ship's agent that the sand from West Beach, Long Island, be removed with the alternative that the OSC would begin to remove the sand in 24 hours. On 30 August, 1972, the ship's representatives sought a restraining order in Federal District Court to prevent the government from taking such action. The OSC, EPA oceanographer and lawyer, and a USCG lawyer appeared in court on 31 August, 1972. The restraining order was not granted, however, the court gave the ship's agents nine (9) days to develop a satisfactory alternative. The ship's agents then proceeded to conduct an experiment for removing oil which consisted of mixing sorbent into the beach and then floating it out with the rising tide. This experiment, described in detail by Welsh and Lee (1972), was carefully monitored by the EPA and its consultants and was determined to be unsuccessful.

On 15 September, 1972, the CG made arrangements for the removal of the sand from West Beach, Long Island. Monitoring of the cleanup operations continued until 16 October, 1972, the final beach inspection was conducted by the EPA and the EPA's beach consultant, Carl Foget of URS, Research Co., San Mateo, California.

Containment and Cleanup Operations:

Table 1 is a log of cleanup operations following the spill in Casco Bay. When the pilot boat of Portland Pilots, Inc., first noticed oil escaping from the Tamano at 0200 on 22 July, they immediately notified Sea Coast Ocean Services (SOS) of the spill. Tamano began to pump oil from the ruptured tank to other available tanks on the ship. SOS dispatched a speedboat to investigate the size and the nature of the spill and began mobilizing men and equipment. At 0300 the SOS speedboat radioed for a full barge of booms and rigging which arrived at the ship at 0410 with the 1200 feet of 3 ft containment boom. Collection and removal of surface oil began immediately. However, after completely circumnavigating the vessel more oil was discovered toward the starboard bow indicating the probable location of the leak.

At daylight a helicopter from Maine Helicopter Service was used to assess priorities in the cleanup operations. An SOS diver was unable to investigate the damage because of the thick layer of oil trapped beneath the hull. As the first boom was not long enough to surround the ship, the OSC, after aerial inspection requested complete booming, SOS sent for additional equipment from Cianbro Corporation and Texaco. Cianbro Corporation also furnished air compressors, pumps, barges and men for beach cleaning. The oil was believed sufficiently contained by the evening of 22 July and removal of oil from the boom continued through the night. By 23 July, however, helicopter flights revealed substantial additional oil escaping. The OSC surmised that oil trapped beneath the hull was being moved out from underneath the vessel by the currents and rising to the surface beyond the booms. He decided that the containment of the spill was beyond the capabilities of the equipment available and activated additional contractors and equipment from the Boston area, as well as an additional 1,000 ft boom from Portland Pipeline.

At 1600 on 23 July, Coastal Services of Massachusetts became the prime cleanup contractor, with SOS performing duties as subcontractor. The cargo in the damaged tank was removed by 25 July. Before Tamano sailed on 4 August, attempts were made to force the trapped oil from beneath her hull using compressed air. This was only marginally successful, because oil escaped when the ship was moved.

TABLE 1

LOG OF OIL CLEANUP OPERATIONS

CASCO BAY, MAINE

TIME (EDT)	DATE	ACTIVITY
0120	22 July 1972	Tamano struck Soldiers Ledge in Hussey Sound.
0200	22 July 1972	Accident first noticed when Tamano anchored. Pilot notified Sea Coast Ocean Services (SOS). Tamano began to transfer from damaged tank.
0200	22 July 1972	SOS dispatched a speed boat to investigate the nature of spill and began to mobilize men and equipment.
0243	22 July 1972	Portland Pilots notified USCG of the oil spill.
0300	22 July 1972	SOS boat radioed for a full barge of booms and rigging.
0400	22 July 1972	USCG personnel arrive on the scene.
0410	22 July 1972	Booms and rigging arrive at the scene.
0430	22 July 1972	Captain D. J. McCann, USCG, predesignated On-Scene Coordinator (OSC) was notified of the spill.
0500	22 July 1972	OSC arrived at Coast Guard Station, South Portland, to assume duties.
0530	22 July 1972	Booms placed from bow to midship of Tamano.
0600	22 July 1972	Environmental Protection Agency, Region I, was notified.

TABLE 1

TIME (EDT)	DATE	ACTIVITY
daylight	22 July 1972	Maine Helicopter Service was used to assess priorities in cleanup operations.
0815	22 July 1972	OSC made first overflight of the spill.
0930	22 July 1972	Tamano completely boomed upon direction of OSC.
1600	22 July 1972	OSC made second overflight of the spill. Coastal Services of Massachusetts became the prime cleanup contractor with SOS serving as a subcontractor.
1600	22 July 1972	Oil washed ashore on the islands in the immediate vicinity of the Tamano anchorage. EPA representatives arrived on the scene. USCG and EPA representatives boarded the Tamano and sampled the contents of the damaged tank.
	23 July 1972	Overflight by USCG aircraft showed that oil was escaping from the hull of the Tamano and surfacing beyond the booms deployed on 22 July 1972. OSC, in cooperation with Texaco, Inc., called contractors in the Boston area for additional booms and skimmers. Beach cleanup began.
	23 July 1972	Additional pumps were called to assist transfers of oil from the damaged tank to other tanks on the Tamano.
	23 July 1972	Waterborne oil was dispersed by tidal action and 60% of Hussey Sound was covered with heavy, black streaks and rainbow films. Affected areas included: Cousins Island to the east; southward

TABLE 1

TIME (EDT)	DATE	ACTIVITY
	23 July 1972	from Spring Point to Cape Elizabeth; Crescent Beach.
	23 July 1972	Meeting of interested parties held to formulate cleanup plans. 24-Hour Coast Guard watch on Tamano instituted and necessary "Notice To Mariners" issued.
	24 July 1972	EPA and USCG representatives made overflight of affected area. Southward drift of oil extended to Prouts Neck, near Old Orchard Beach. Conference with OSC, EPA, cleanup contractors and Texaco, Inc., to review and coordinate cleanup.
	25 July 1972	Additional coordination meetings conducted by OSC and EPA representatives. EPA contracted with VAST, Inc., to make damage assessment.
	25 July 1972	Aerial survey by VAST, Inc., personnel. Oil still in Hussey Sound with streaks extending to the south and east. There was little evidence of northward extension beyond Cousins Island and Great Chebeague.
	25 July 1972	Damaged tank cleared of cargo.
	29 July 1972	Oil reached Ogunquit, Maine.
	25-30 July 1972	Coordination meetings were held and overflights were made.
	24, 25, 27, 28 31 July 1972	Maine Department of Inland Game conducted surveys.
	1 Aug. 1972	Corps of Engineers, U. S. Army conducted sonar sweeps of Hussey Sound to check for uncharted

TABLE 1

TIME (EDT)	DATE	ACTIVITY
	1 Aug. 1972	hazards to navigation. Joint survey conducted by EPA, Maine Sea and Shore Fisheries and the Maine Environmental Protection Department.
	3 Aug. 1972	Corps of Engineers, U. S. Army reported to OSC that no uncharted hazards were located. Oil within booms removed and discharge of cargo completed. Texaco, Inc., finds onshore site to deposit oily debris.
	4 Aug. 1972	Tamano cleared port for dry-docking. More oil escaped.
	1-17 Aug. 1972	EPA conducted survey of cleanup procedures.
	17 Aug. 1972	EPA written recommendations for cleanup procedures submitted to OSC.
	18 Aug. 1972	EPA recommendations forwarded to representatives of ship's owners.
	24 Aug. 1972	EPA representatives observed oil from West Beach, Long Island, leaching back into water column and recommended OSC begin immediate sand removal in that area.
	29 Aug. 1972	OSC notified ship's agent that sand be removed from West Beach, Lond Island, or OSC would begin sand removal in 24 hours.
	30 Aug. 1972	Ship's agent sought restraining order to prevent government from taking such action.

TABLE 1

TIME (EDT)	DATE	ACTIVITY
	31 Aug. 1972	OSC, EPA Oceanographer and Lawyer and USCG Lawyer appeared in court. Restraining order not granted, but ship's agents were given nine (9) days to develop methods to remove oil.
	11 Sept. 1972	Ship's agents conduct experiment to test method for beach cleanup.
	13 Sept. 1972	USCG made arrangements to remove sand from West Beach.
	15 Sept. 1972 16 Oct. 1972	Beach cleanup operations were conducted.

Beach cleanup operations began on 23 July. Straw was used to absorb the oil both in the water and on the beaches. Barges transported straw to the beaches and returned with trucks filled with oil-soaked straw and debris for dumping on the mainland. Oil-soaked straw, not picked up before the tide reached it on the beaches, often floated to locations which were otherwise unaffected. Skimmers used to remove oil from the water surface became clogged when they encountered the floating seaweed and oil-soaked straw. Small boats were also deployed with crab nets to pick up the floating wrack.

The rocky coastlines were also cleaned by hot water in pressure hoses. Problems were encountered, because although a secondary source of water was used to help remove oil from resettling on unaffected areas, some resettlement did occur. Oil-soaked seaweed was harvested and raked into piles to be dumped.

The most seriously affected beach was West Beach on Long Island. The ship's agents, who took over responsibility for cleanup from Texaco, Inc., on 11 September, conducted an experiment in beach cleaning which has been described earlier (Welsh and Lee, 1972) and was deemed unsuccessful. The beach was subsequently cleaned by removal of the top six inches of sand by 16 September.

Texaco was unable to find a disposal site for oily debris in the Portland area until 3 August. Sand from West Beach was shipped to sanitary land fill at Brunswick Naval Air Station, Brunswick, Maine. The oily debris was burned at an approved site in Gray, Maine.

Preliminary Survey:

The shore areas around Hussey Sound were inspected by the VAST field team on 25 and 26 July, three and four days after the spill. Most of the intertidal area was sloping or vertical rock faces, except for West Beach, a long sandy strip on Long Island immediately offshore from the anchored tanker. A very small proportion of the immediate area could be considered mud flat.

The vertical rock faces were heavily coated by a distinct band of oil varying from 2 ft wide to six ft wide, beginning about one ft below the high water mark. On the rock faces just north of West Beach on Long Island, barnacles had apparently died and were washed off the oiled zone, whereas outside that zone the barnacles appeared healthy. There were no snails. Some _Fucus_ was still attached within the oily band. Much heavily oiled _Fucus_ was floating about in the tidal currents, stranded on floating objects, such as lobster buoys and coming ashore on beaches. Some boats were deployed scooping up the seaweed with crab nets and towed booms.

The sloping rock faces presented a greater area of intertidal zone and proportionately greater areas received a heavy coating of oil. Barnacles and _Fucus_ were still in place, though heavily coated. Snails (_Littorina_) were present throughout, but were unattached, lying with the closed operculum upward rather than in their normal grazing position.

The sandy beach at Long Island, the most heavily contaminated of the beaches in the immediate area, was paved with oil over a swath of 80 - 90 ft wide, extending from about 8 ft below the high tide line. The heavy oil penetrated to a depth of 4 - 6 inches. Below that the sand appeared clean. A swath had been bulldozed clean, but was being reoiled through leaching from the paved areas and continued leakage from the tanker. Straw had been used to soak up the oil. This, too, was washed off the beach and added to the oily seaweed wrack floating in the water.

In the areas of mud flat visited on the northern shore of Cow Island, the oil washed ashore and collected in the marsh grasses inshore of the mud flats. No pavement was formed on the sediment surface such as occurred on the beaches, but as one walked across the flat, oil would ooze up out of the sediments into freshly formed footprints.

Nature of the Field Study:

From the preliminary survey, it appeared that the biota of the intertidal zones was in danger from both smothering and the toxic effects of oil, while the subtidal areas could be affected by dissolved oil in the water column, leaching from the shore zones, sedimentation and offshore sediment transport. A program was developed to monitor these potential effects using chemical techniques to quantitatively determine the presence of the pollutant. These were combined with ecological techniques for detecting stress through changes in abundance and species diversity, with special attention to amphipods as indicative organisms.

SECTION IV

METHODS

Field Methods:

Two rocky intertidal stations were established, (Figure 1), one on a vertical rock face on Long Island and one on a sloping rock on Cow Island. An intertidal mud station was established on Cow Island, and a subtidal station was established in 20 - 25 feet of water on the lobster grounds north of Long Island. Comparable control stations were established at Bailey and Orrs Islands to the northeast (Figure 1).

Three surveys were conducted, 25 to 31 July; 6 to 13 September; and 1 to 5 November.

Samples were collected in duplicate, labeled and logged in the field and initialed by two investigators. A chain of custody procedure was followed such that each sample contained its survey number in Roman Numerals and a sample number in Arabic numbers. Upon return from the field, biological samples were frozen; water and sediment samples were refrigerated.

Special handling procedures were used with all samples for chemical analysis. Plastic containers were avoided at all steps. The glass bottles used for water and sediment were cleaned according to procedures designated by the EPA Edison Water Quality Research Laboratory. New bottles were washed with detergent, rinsed sequentially in steam distilled water (APHA spec), acetone, methanol and pentane (all Nanograde), then air dried and capped. The caps were lined with aluminum foil. Bottles that were reused in subsequent field trips were washed with detergent and flushed with distilled water and pentane. Biological samples were collected and stored in aluminum foil.

Each of the rock stations were sampled by a direct count of organisms within two 10 x 10 cm grids on each of the four biotic zones of the intertidal surface. After counting, the organisms within each grid were scraped from the rock and returned to the laboratory for closer inspection. On the first survey, a swath of rock, 1 1/2 feet wide, from the high to the low water levels, was scraped bare for subsequent appraisal of the rate of resettlement on cleared areas. Two types of organisms (a primary producer and a grazer) were collected for analysis by gas chromatography.

Intertidal mud areas were sampled by collecting sediment and infauna from two 30 x 30 x 20 cm grids. The samples were screened (1mm mesh) to separate the biota which was then returned to the laboratory for counting. Samples of mud and soft shell clams (Mya arenaria were collected for gas chromatography.

Subtidal benthic samples were collected by divers, screened and analyzed in the same manner as the intertidal mud. Sediment and lobsters were taken for gas chromatograpy. The lobsters were purchased on-site at the time of each survey from a local lobsterman who was pulling traps in the area.

Water samples were taken one to two feet off the bottom at the subtidal stations and just below the surface at the intertidal flats. Midbay water samples were taken at can buoy "7" from the surface and from 30 feet deep to determine the hydrocarbon content of the water flushing the area. Water samples were taken on all surveys and analyzed on Surveys I and III.

The rookeries at Ram Island, Inner Green and Outer Green Islands were surveyed on foot to assess gross deleterious effects of gulls, cormorants and waterfowl by counting dead and oiled birds.

Beach sand was collected from three depths (0-10, 10-20 and 20-30 cm) at two stations on West Beach, Long Island. Samples were collected immediately after the spill and again after the beach cleanup operations to determine their oil content.

Laboratory Methods:

The screened portions of the benthic and intertidal samples were shaken in 10% formalin with a biological stain (rose bengal) which aided in the final separation of animals from the course fraction of the sediment. The numbers of species and numbers of individuals were determined for the sediment infauna and also for the rocky intertidal grid samples. Subsequently, the fauna were preserved in 70% alcohol. Identifications of amphipods are known to present difficulties (Sanders, 1956) and were therefore made only to type specimens, with final identification pending confirmation by a specialist, if necessary. Polychaetes were difficult to recover in good condition and those which were mutilated beyond recognition were placed in typed categories, so that a good estimate of the species diversity could be made without their identification.

Representatives of each species subjected to chemical analysis were weighed, dried to constant weight and re-weighed to obtain a conversion factor of wet weight to dry weight for relating laboratory results to field concentrations. Wet weights were used when they were more appropriate.

The analytical methods used to determine the presence of No. 6 fuel oil were based on modifications of the procedure used by Blumer et al (1970, 1972) for No. 2 fuel oil. For the extraction of total lipid components, samples of sediment and beach sands weighing approximately 200 gm were placed directly in Soxhlet thimbles. Shellfish were shucked and the animal plus its fluids were homogenized in a commercial blender before placement in a thimble.

Lobsters were homogenized with their shell but seaweeds were chopped, because they stalled the blender. Wet weights were taken, and the samples were extracted for a minimum of 20 hours with re-distilled, reagent grade anhydrous methanol and benzene. The methanol-benzene extract was transferred to a separatory funnel and extracted four times with 50 ml of pentane. Solids in the extract (biological samples) were shaken with pentane three times. The pentane portions were combined and evaporated to a small volume (5 - 10 ml) by passing N_2 over them. They were next saponified in 150 ml of 60% 0.5 KOH in methanol, 20% water and 20% benzene (refluxed 1 - 2 hours) to remove wax esters, fatty acids and triglycerides. The saponified mixture was repartitioned into pentane three times, using aqueous NaCl to precipitate the salts. The remaining non-saponifiable portion contained any fatty alcohols, sterols, pigments or fuel oil hydrocarbons which were present in the pentane, was then evaporated with N_2 to a volume of 1 - 2 ml. The concentrated solution was passed first through a column of precipitated copper to remove sulfur, then through a chromatographic column packed with 2.4 g alumina over 3.6 g silica gel, which had been activated at 250°C and 120°C respectively, deactivated with 5% by weight of water and washed with pentane. For biological samples the ratio of the silica gel portion to the alumina was increased to enhance the separation of pigmented materials from the fuel oil and 0.1 part benzene was added to the pentane to elute the hydrocarbons. The pentane was evaporated and the residual hydrocarbons were weighed.

The extracted hydrocarbons were dissolved in a small volume of CS_2 and subjected to scanning infrared (Perkin-Elmer, Model 727) analysis to confirm that the remaining lipids had been removed by the column chromatography. An absorption band between 1700 nm and 1750 nm would detect incomplete separation and the sample would be re-columned.

Control samples of No. 6 fuel oil were carried through the entire procedure with 75% recovery by weight. Fractions eluted from the chromatographic column were scanned on an ultraviolet (Beckman D.U., 2400) spectrophotometer from 230 to 260 nm to assure that the aromatic portions were being eluted.

After column chromatography, the samples were injected into a Varian Aerograph 2860 gas chromatograph equipped with a split capillary injecture port. A SCOT (support coated open tubular) column, OV-101, 50 ft long with 0.02 " I.D. was used. Automatic temperature programming was set for an 80°C injection, rising at 15°C/min to 300°, followed by a 12 min post-program hold.

Addendum to Methods:

Fucus taken during the first and second surveys and Ascophyllum from the first survey only, were so thoroughly coated with oil at the experimental stations that they were weighed, washed in benzene, dried one hour at room temperature and re-weighed to determine the weight of oil removed. Control samples were treated in the same manner to determine any weight changes associated with the treatment alone. Corrections for water loss were determined to be - 0.25% of gross weight for Fucus and - 1.3% for Ascophyllum, and these corrections were applied to the results of the benzene treatment. Beach sands from Long Island were treated by the same method.

SECTION V

CHROMATOGRAPHIC RESULTS

Chromatogram of No. 6 Fuel Oil:

The method of interpreting the chromatographic results was based on that of Blumer et al (1970, 1972) for No. 2 fuel oil, except that the column was OV-101 rather than Apiezon L and the programmed temperature rise was more rapid and reached a higher level, commensurate with the boiling fractions in No. 6 oil. In the chromatogram of the No. 6 oil from the Tamano (Figure 3), the characteristic unresolved boiling envelope of isomeric hydrocarbons started at about C-14, peaked between C-21 and C-23 and diminished rapidly after C-28. The position of the envelope was characteristic for No. 6 and easily differentiated from the characteristic envelope of a typical No. 2 oil (Figure 4) run under the same conditions. Moreover, although the boiling envelope for a high pour No. 6 oil supplied by the EPA New England Regional Laboratory was similar (Figure 5), certain characteristic differences existed between them. In the case of the Tamano oil, there were large peaks of the lower boiling paraffins C-13, C-14, C-15 and C-16 were not seen in the No. 6 of Figure 5. The sequence in which materials are eluted and their relative heights are affected by the type of column and programmed temperature rise. This can lead to variations in locations of peaks and their resolution. Therefore, the column type and temperature program must be consistent throughout the study.

Intertidal Mud Flats:

The intertidal sediments at Cow Island contained oil on all three surveys (Figures 6, 7 and 8). The total amount of hydrocarbon increased between Surveys I and II (Table 2). There was, however, a fresh spill of No. 6 oil in the area by the tanker Aquario two weeks after the Tamano spill, which could account for the added oil. However, no samples of this oil are available for chromatographic comparison. By Survey III, the oil had weathered (Figure 8) and the hydrocarbon level decreased.

All three surveys showed contaminated clams (Figures 9, 10 and 11). The low boilers and the total hydrocarbon concentration in the clams decreased over the three surveys (Table 2). The chromatographs of the water at Cow Island tested on Surveys I and III indicated petroleum hydrocarbons during both surveys (Figures 12 and 13), but the total concentration by Survey III had decreased to less than half that of Survey I (Table 2).

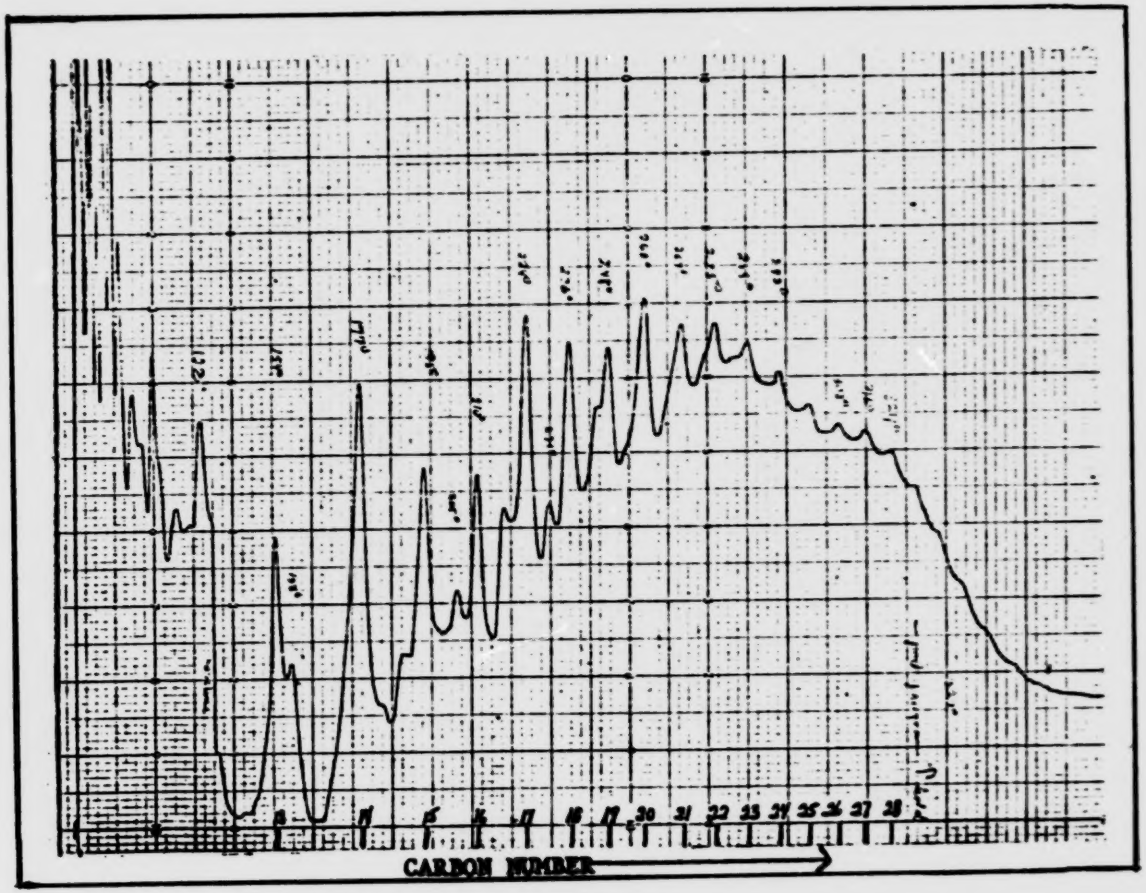


FIGURE 3

Chromatogram of No. 6 Fuel Oil From the Tamano

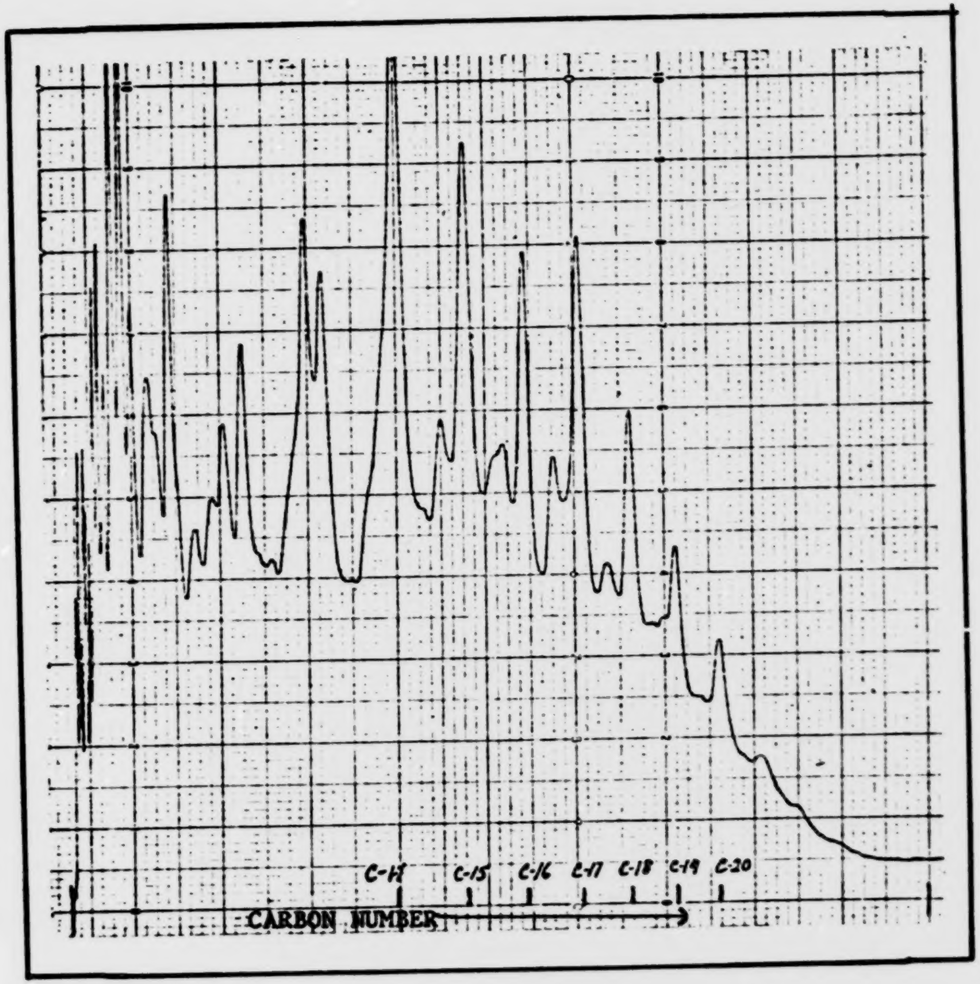


FIGURE 4

Chromatogram of a No. 2 Fuel Oil as it would Appear on an OV 101 Column
Programmed for No. 6 Fuel Oil

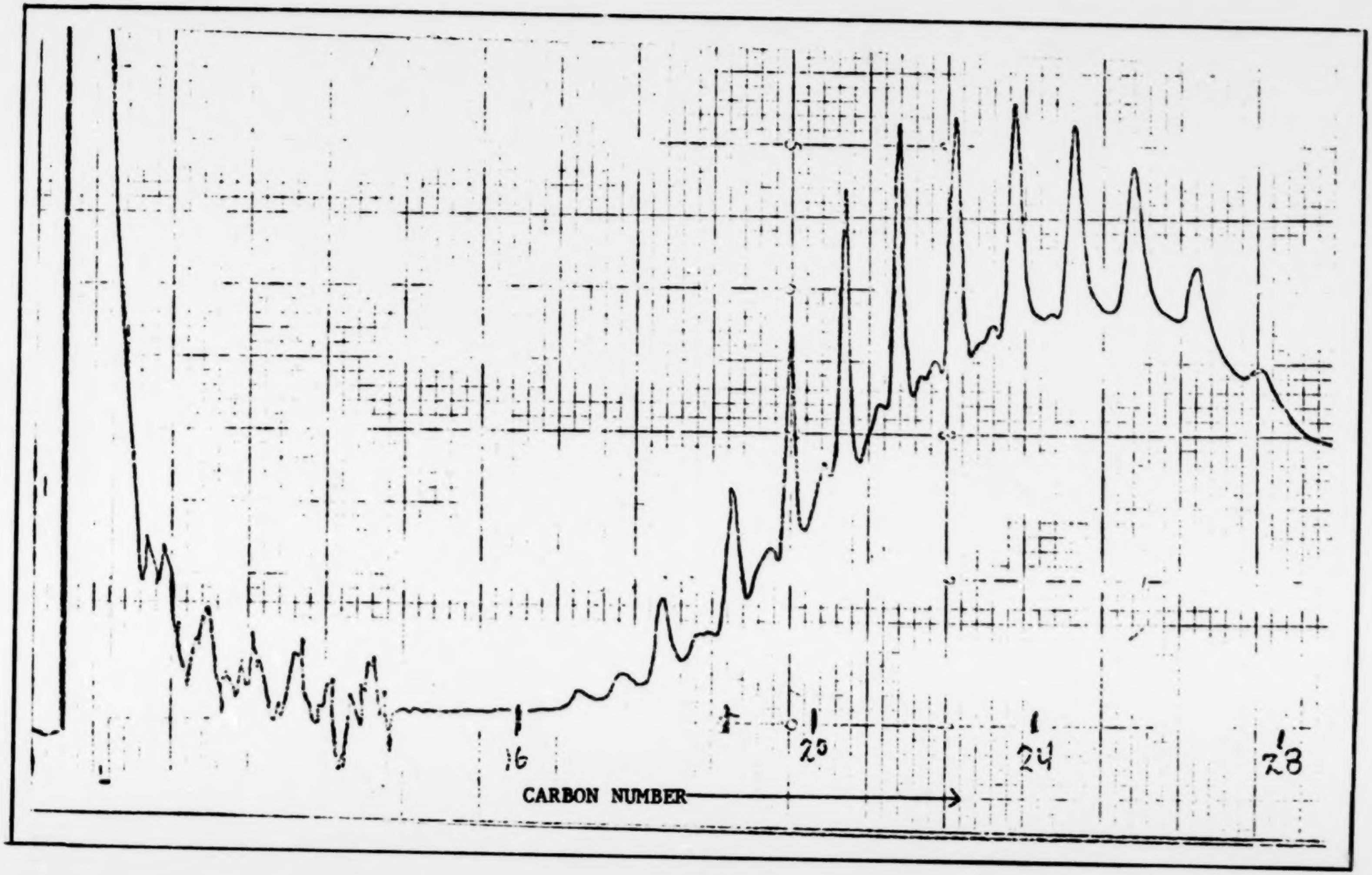


FIGURE 5

Chromatogram of a Typical High Pour No. 6 Fuel Oil
Supplied by EPA New England Regional Laboratory

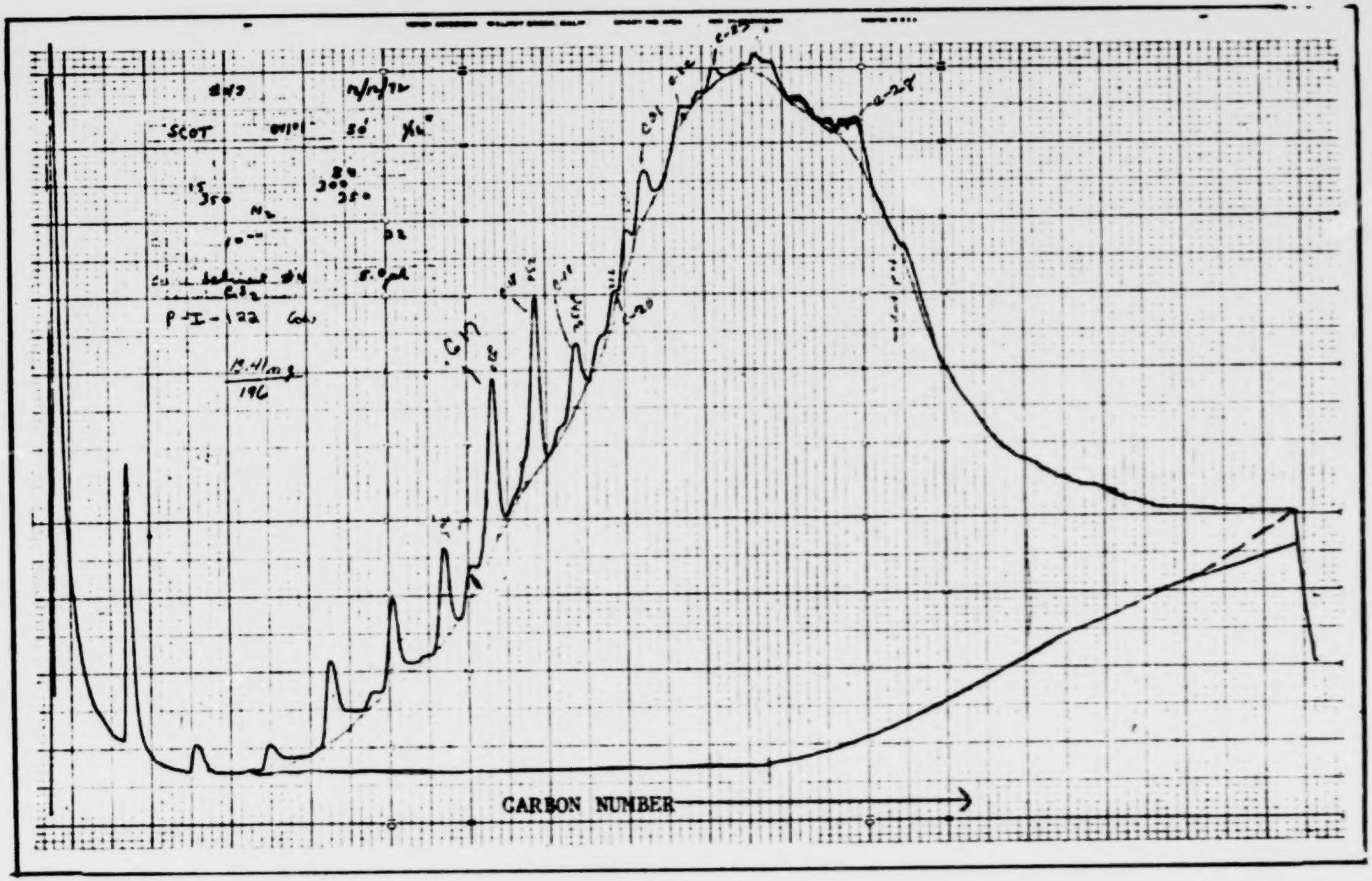


FIGURE 6

Chromatogram of Sediments
Cow Island -- Survey I

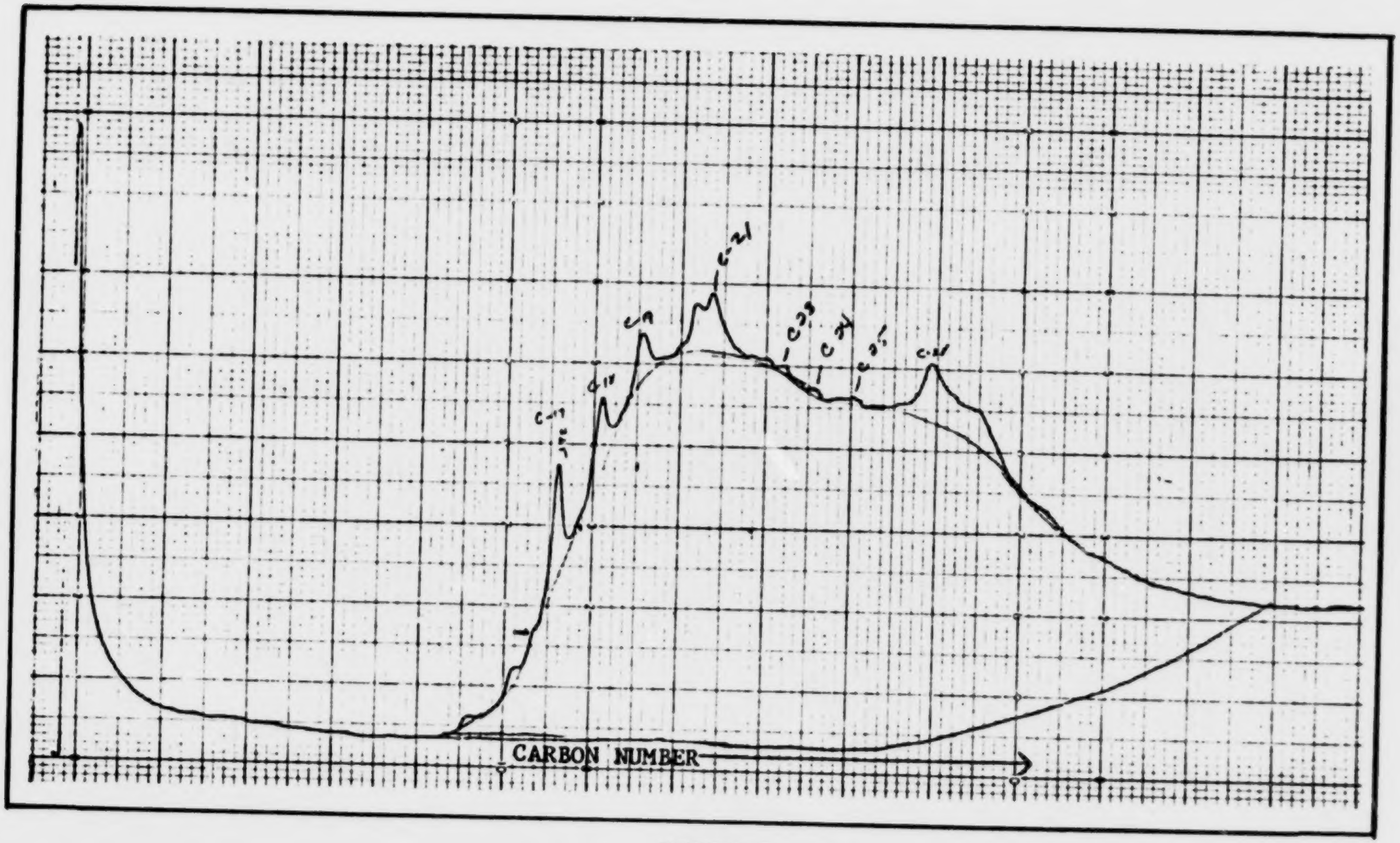


FIGURE 7

Chromatogram of Sediments
Cow Island -- Survey II

TABLE 2

QUANTITATIVE HYDROCARBON ANALYSIS

INTERTIDAL MUD FLATS

SAMPLE	STATION	SURVEY	TOTAL HC MG/KG	μG HC INJECTED	RELATIVE ATTENUATION
Sediment	Cow Island	I	54	268	32
		II	97	113	32
		III	62	154	32
Sediment	Beals Cove*	I	19	42.8	32
		II	35	39.8	32
		III	63	140	32
Clams	Cow Island	I	1,300	16.9	64
		II	360	137.5	64
		III	310	59.7	64
Clams	Beals Cove*	III	114	59.4	32
Water	Cow Island	I	0.9*	36.8	32
		III	0.4	16	32
Water	Beals Cove*	I	0.2**	20	32
		III	1.6**	29.9	32

*Control Stations

**Value is in mg per liter

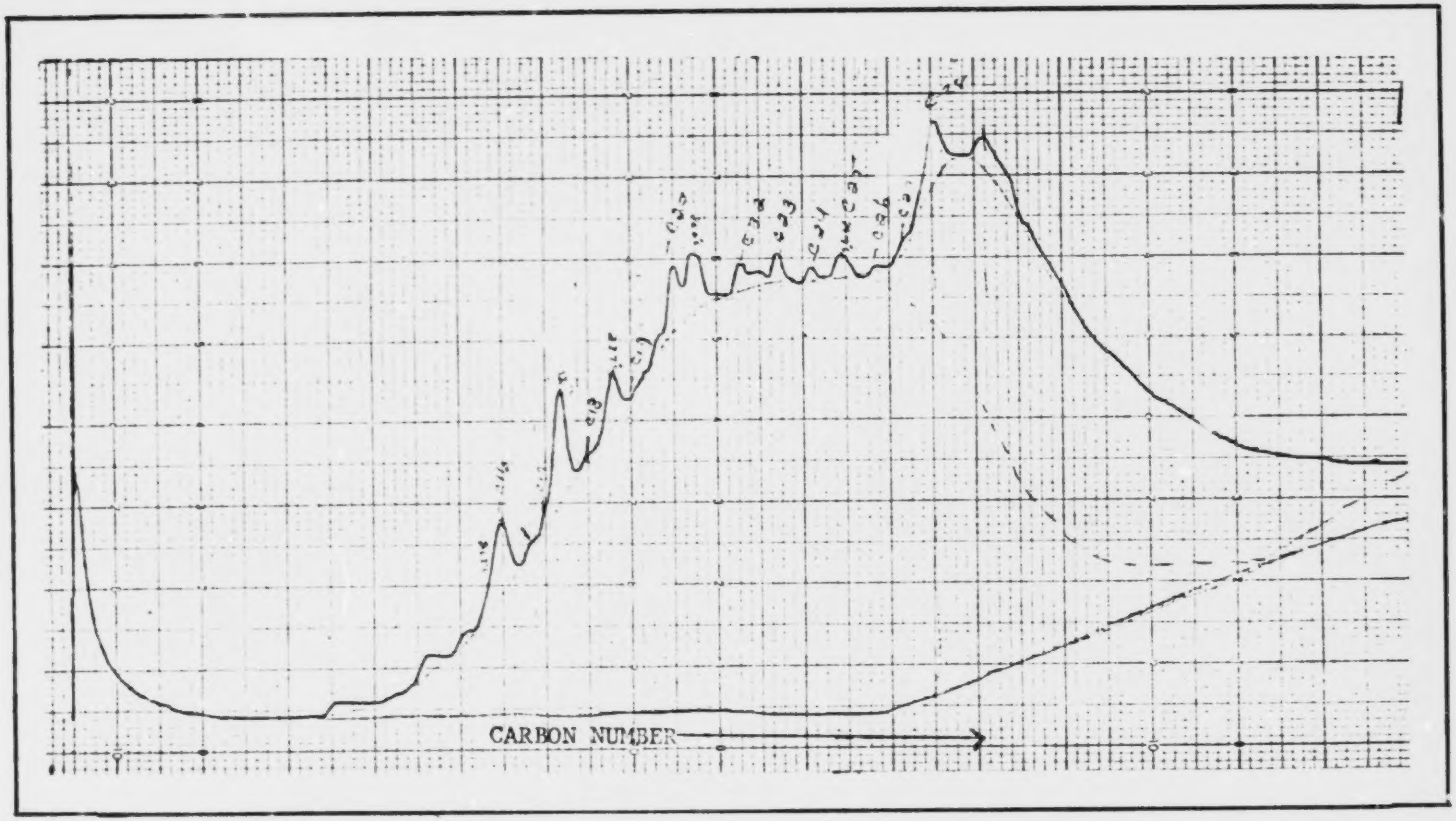


FIGURE 8

Chromatogram of Sediments
Cow Island -- Survey III

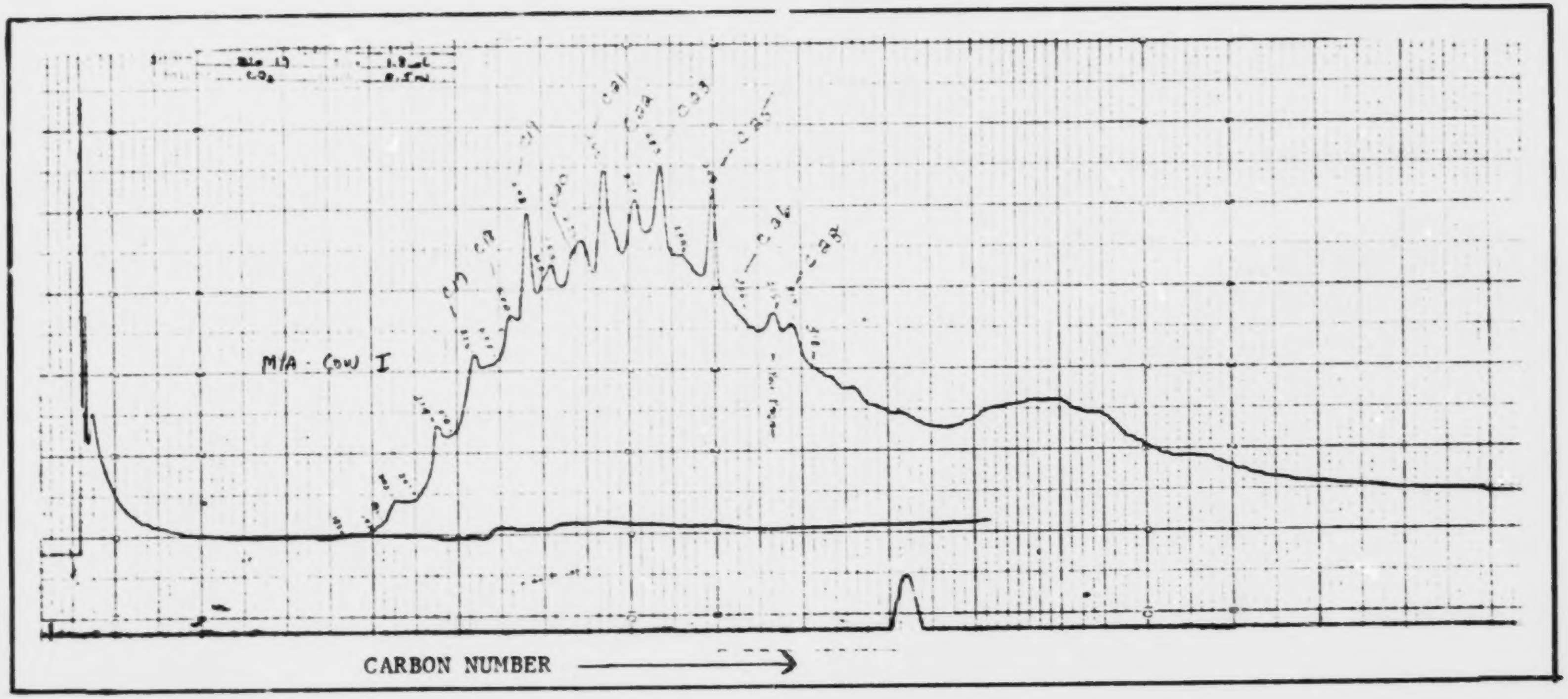


FIGURE 9

Chromatogram of Clams (Mya arenaria)
Cow Island -- Survey I

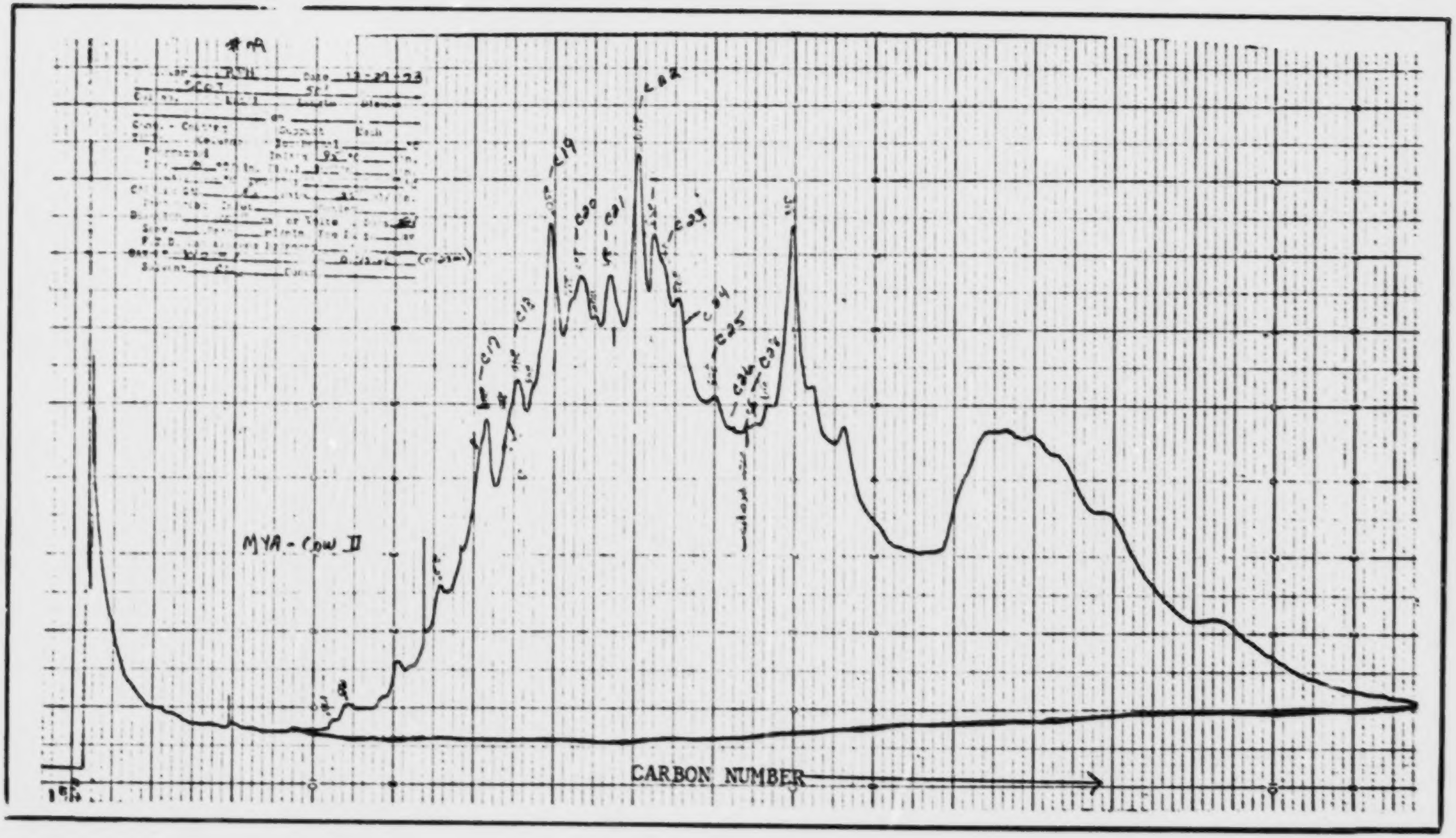


FIGURE 10

Chromatogram of Clams (Mya arenaria)
Cow Island -- Survey II

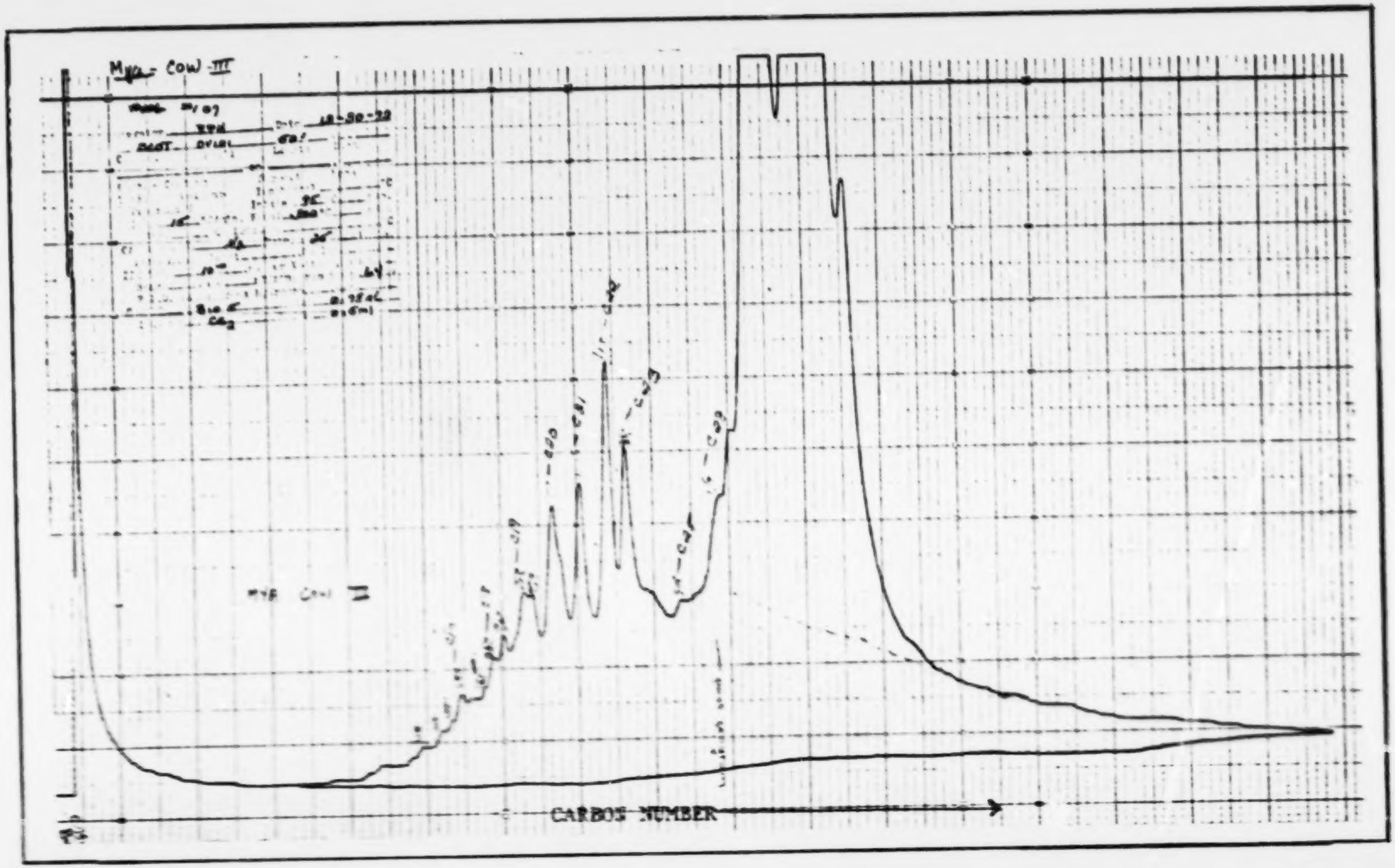


FIGURE 11

Chromatogram of Clams (Mya arenaria)
Cow Island -- Survey III

At the control mud flat on Beals Cove, there was evidence of oil in the sediments during Survey I (Figure 14), but by Surveys II and III, the total hydrocarbon had doubled, then tripled (Table 2) to a level comparable to the Cow Island station with a definite indication of petroleum contamination (Figure 15 and 16).

Clams at Beals Cove during Survey III were similarly contaminated with oil (Figure 17), but the concentrations of total hydrocarbon in their tissues reached only one-third that of Cow Island (Table 2).

The water flushing the Beals Cove station increased dramatically in total hydrocarbon content (Table 2) between Survey I (Figure 18) when no fuel oil was present and Survey III (Figure 19). These curves were interpreted as the more soluble components of petroleum hydrocarbons.

Subtidal Stations:

The sediments at the Long Island station (approximately 20 ft depth), contained oil over all three surveys (Figures 20, 21 and 22). Like the intertidal station at Beals Cove, the concentration of total hydrocarbons increased during the second survey (Table 3).

The lobsters in the Long Island area showed no evidence of fuel oil contamination during Survey I (Figure 23). By Surveys II and III, the total hydrocarbon content had doubled (Table 3) and the peaks along the envelope (Figures 24 and 25) suggest the presence of weathered fuel oil. But, the profile was not distinctive enough to tie it to the Tamano oil. Any build-up was small, because the total hydrocarbon concentration was low compared with the clams and of that total, fuel oil type components were small compared with natural peaks of odd-numbered alkanes (C-21, C-23 and C-25).

The profile of water at this station (Figures 26 and 27) was similar to that at Cow Island with a relatively large portion of the more soluble components (unresolved envelope), but at Long Island there was an increase in concentration of total hydrocarbons between Surveys I and III (Table 3).

The levels of total hydrocarbon in the sediments at the Bailey Island control stations were below those of Long Island during all surveys (Table 3). Survey I, taken seven days after the spill (Figure 28), indicated contamination by oil.

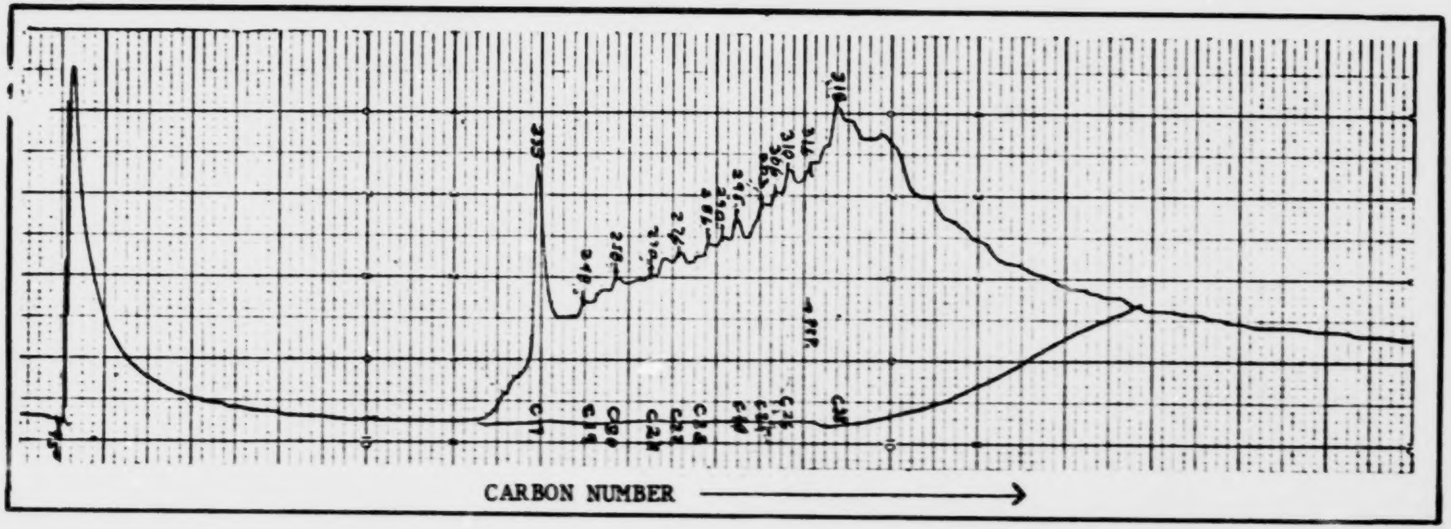


FIGURE 12

Chromatogram of Water
Cow Island -- Survey I

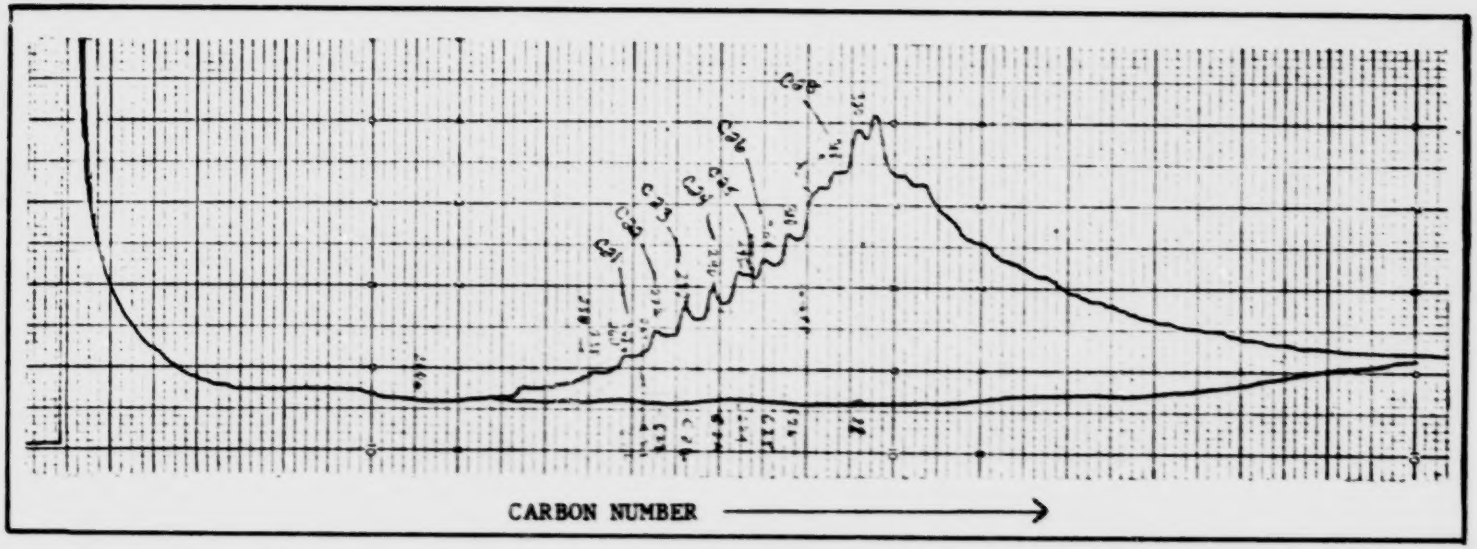


FIGURE 13

Chromatogram of Water
Cow Island -- Survey III

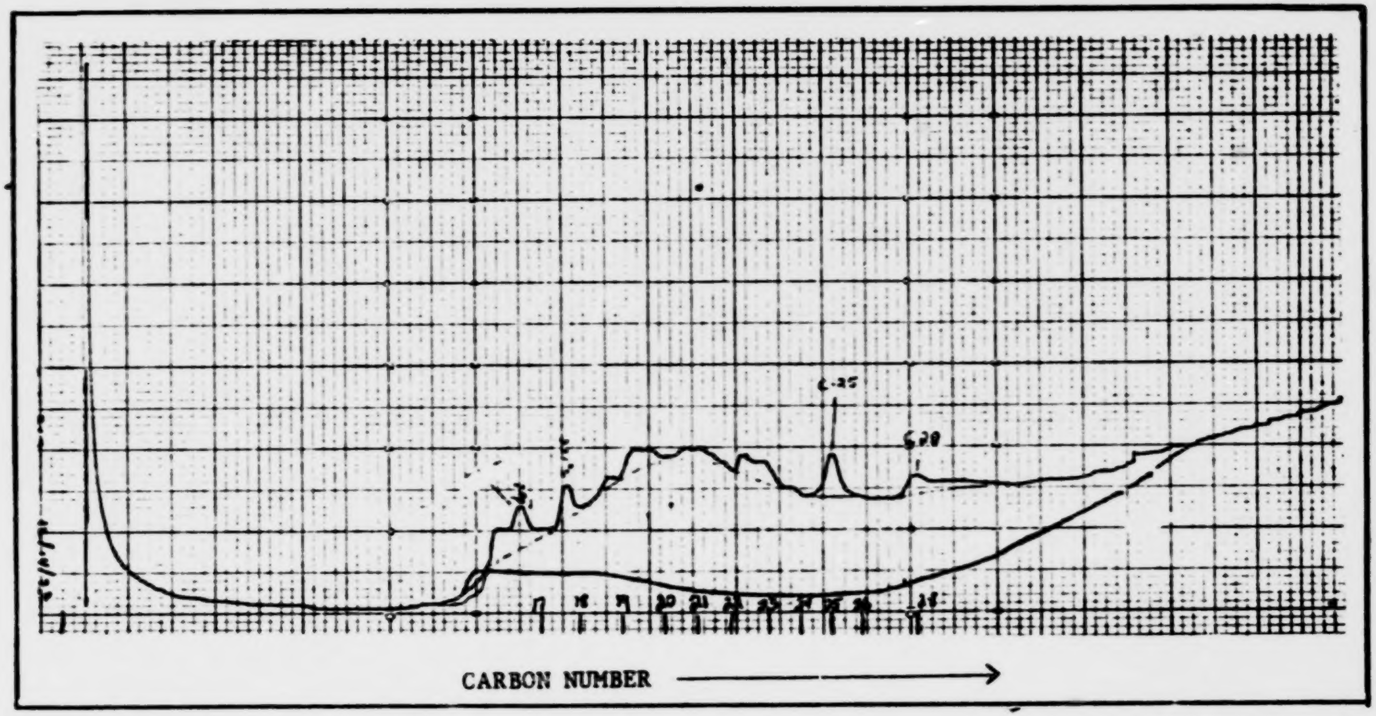


FIGURE 14

Chromatogram of Sediment
Beals Cove -- Survey I

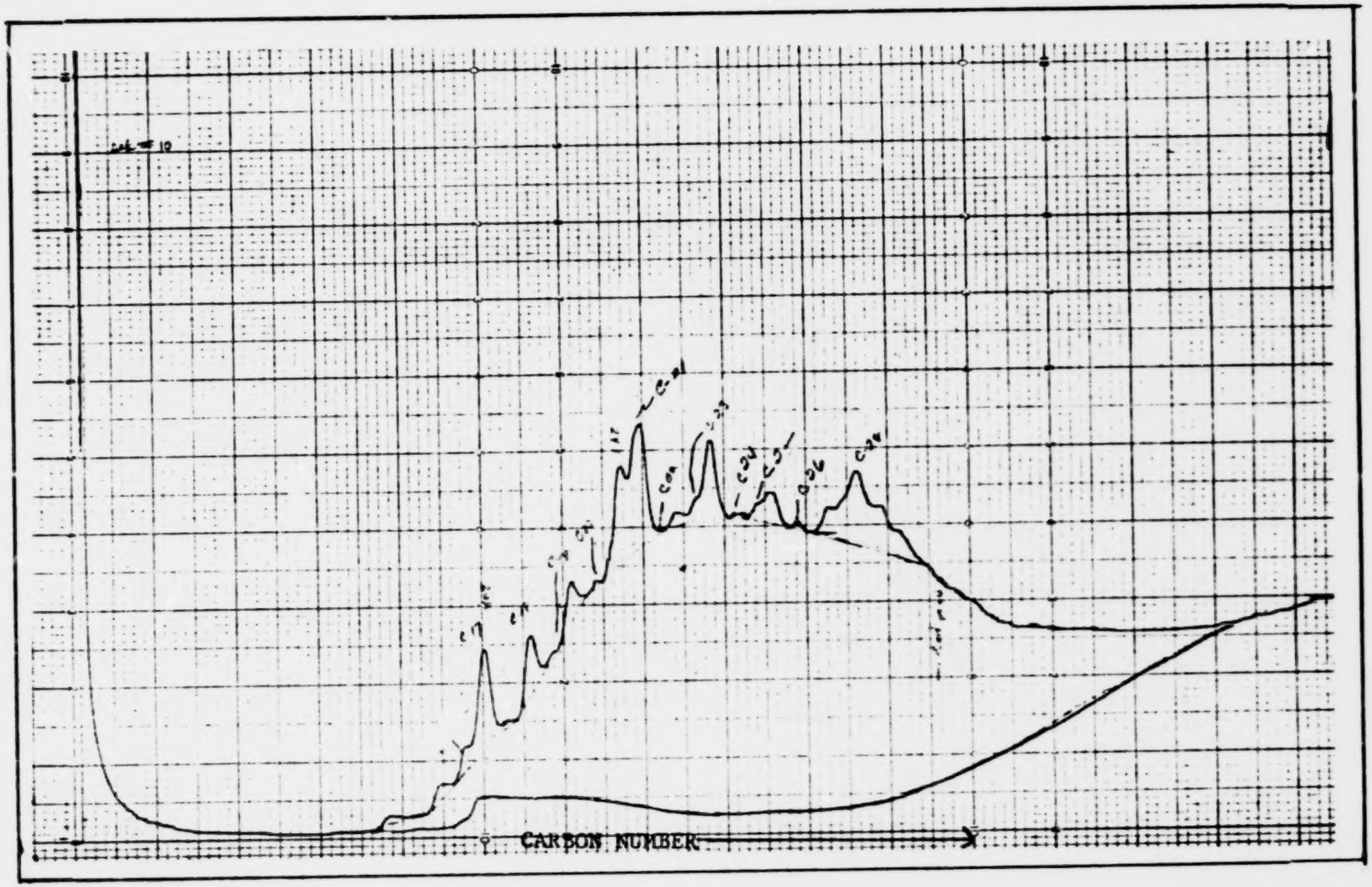


FIGURE 15

Chromatogram of Sediment
Beals Cove -- Survey II

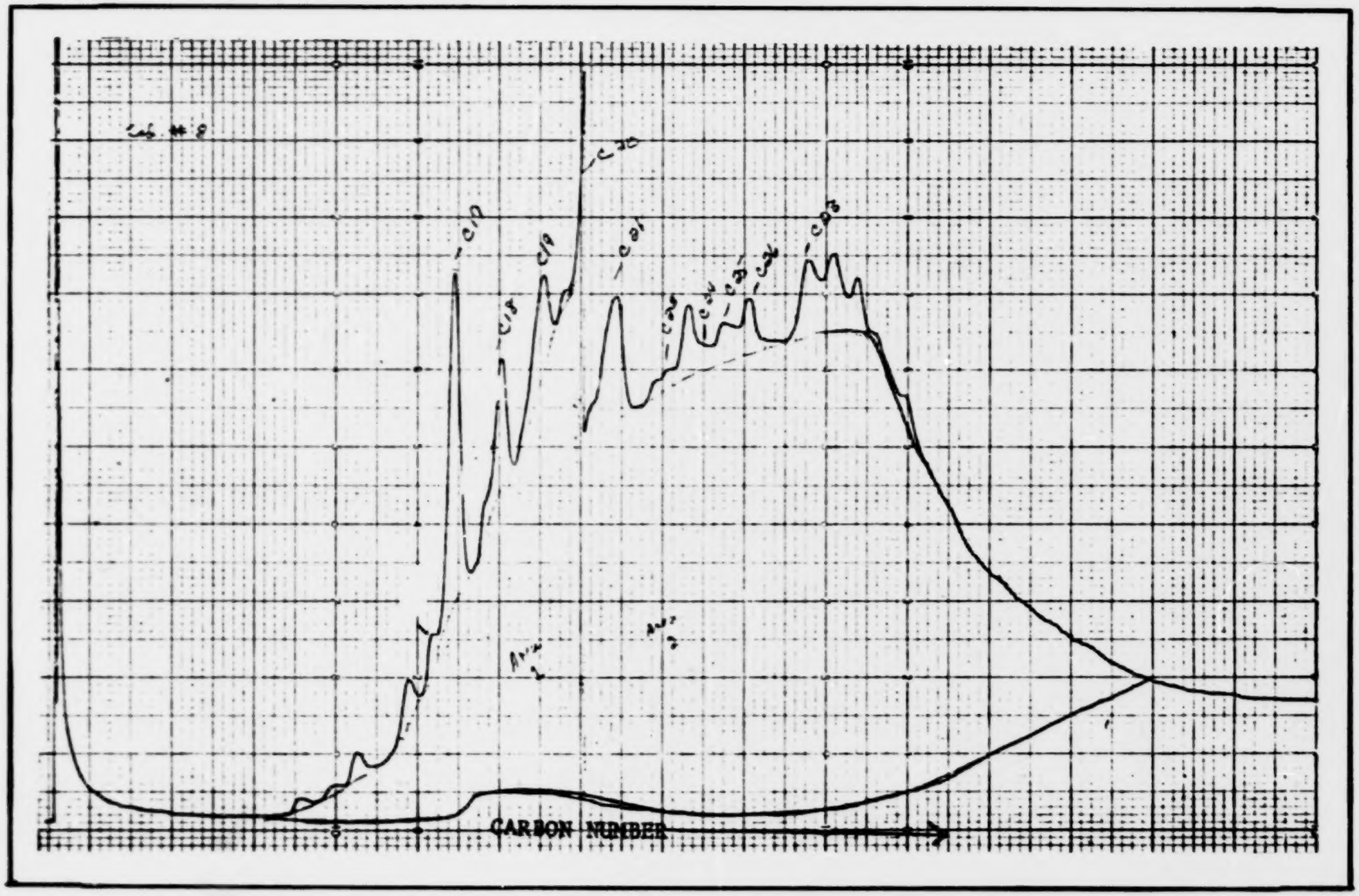


FIGURE 16

Chromatogram of Sediment
Beals Cove -- Survey III

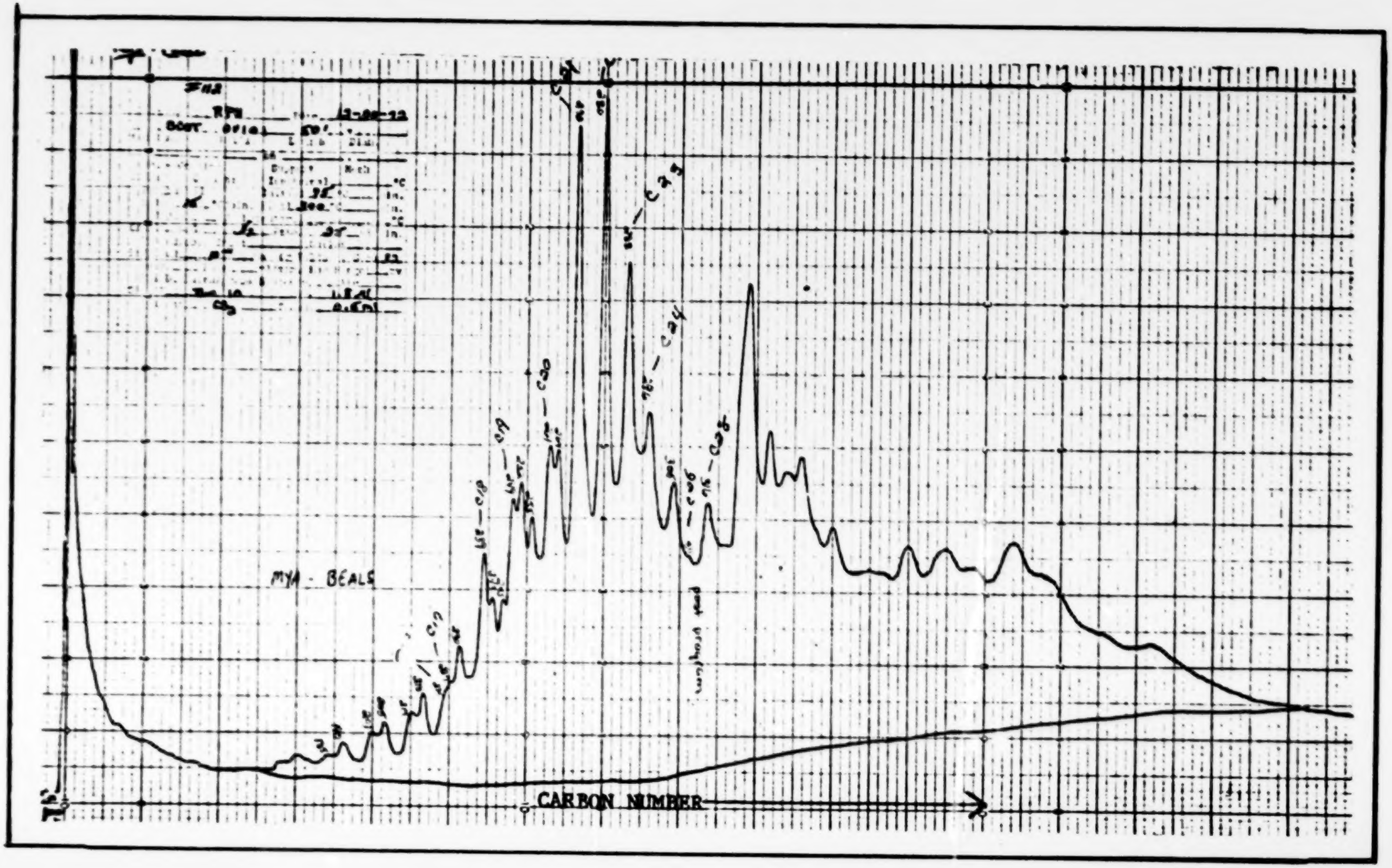


FIGURE 17

Chromatogram of Clams (*Mya arenaria*)

Beals Cove -- Survey III

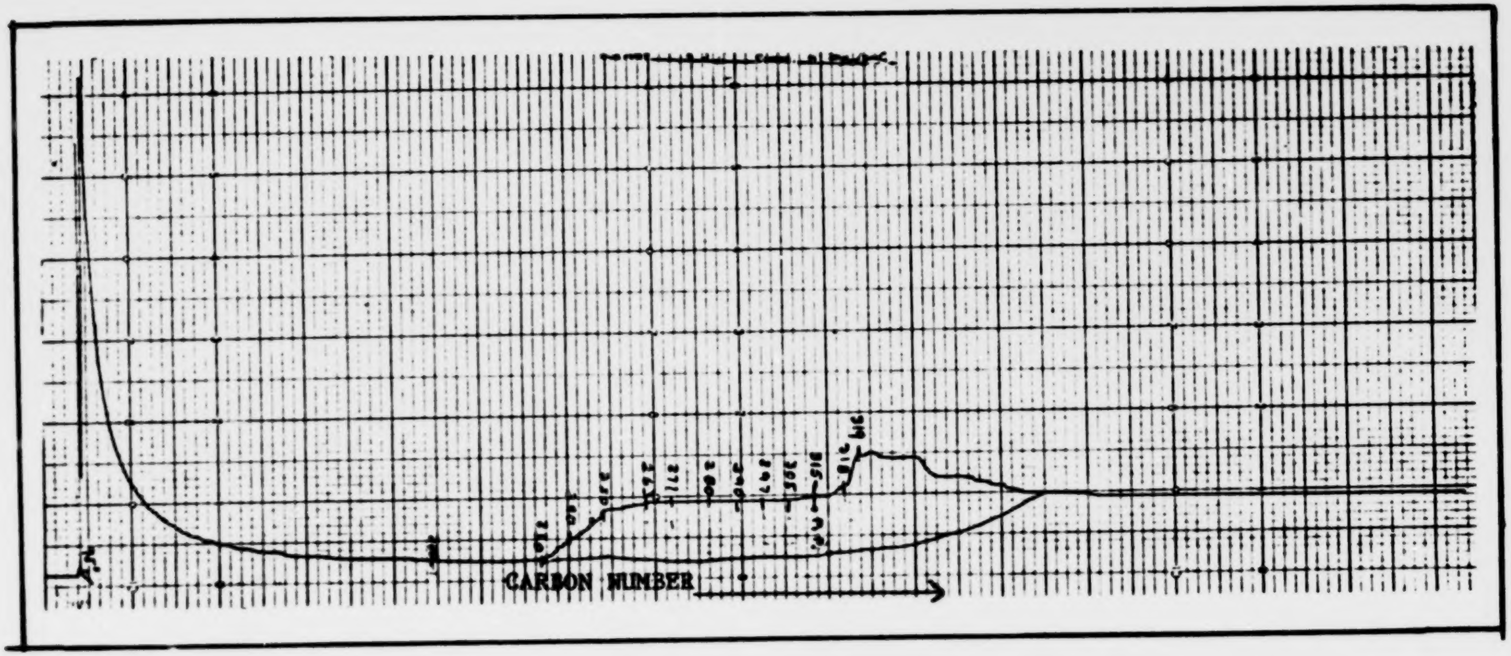


FIGURE 18

Chromatogram of Water
Beals Cove -- Survey I

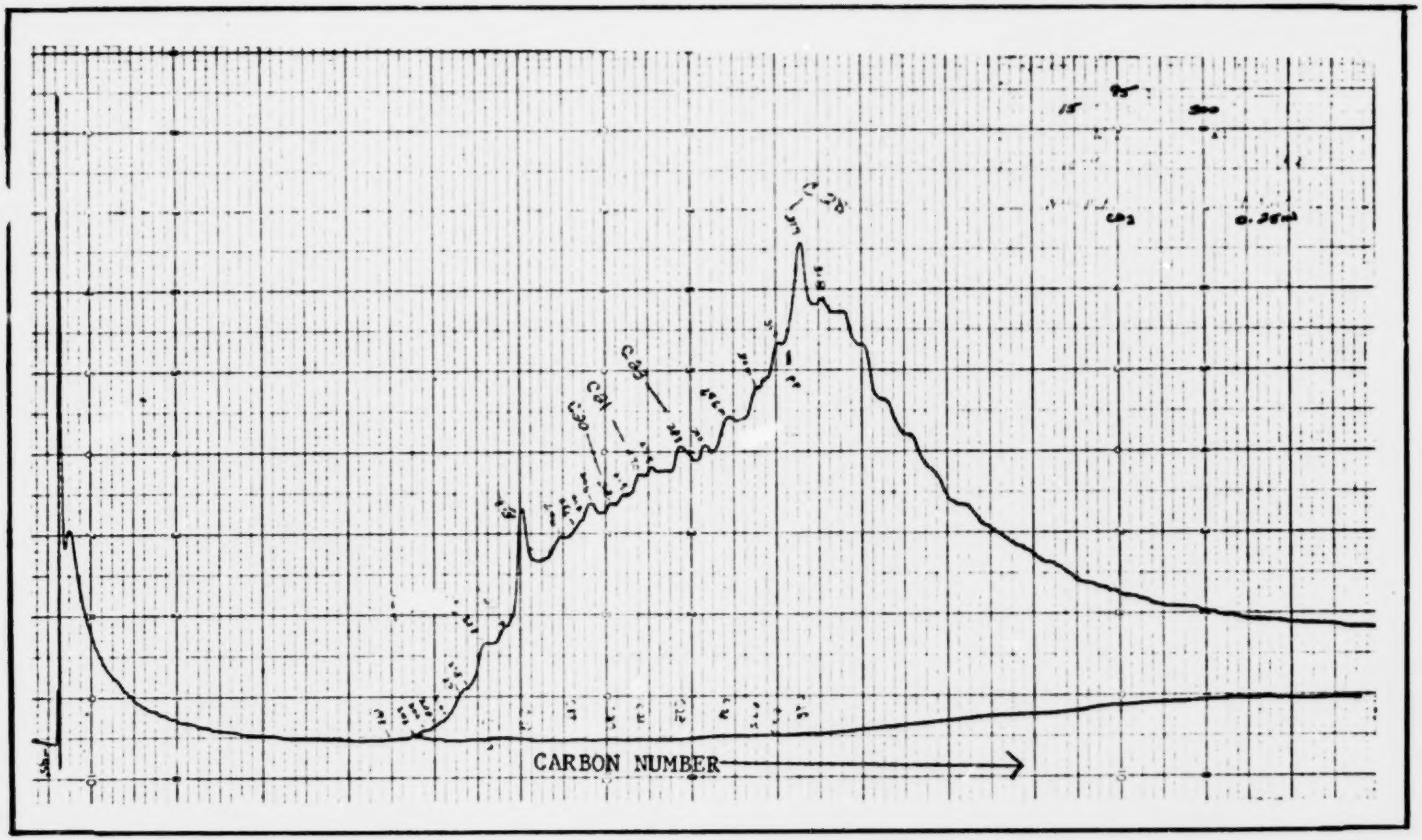


FIGURE 19

Chromatogram of Water
Beals Cove -- Survey III

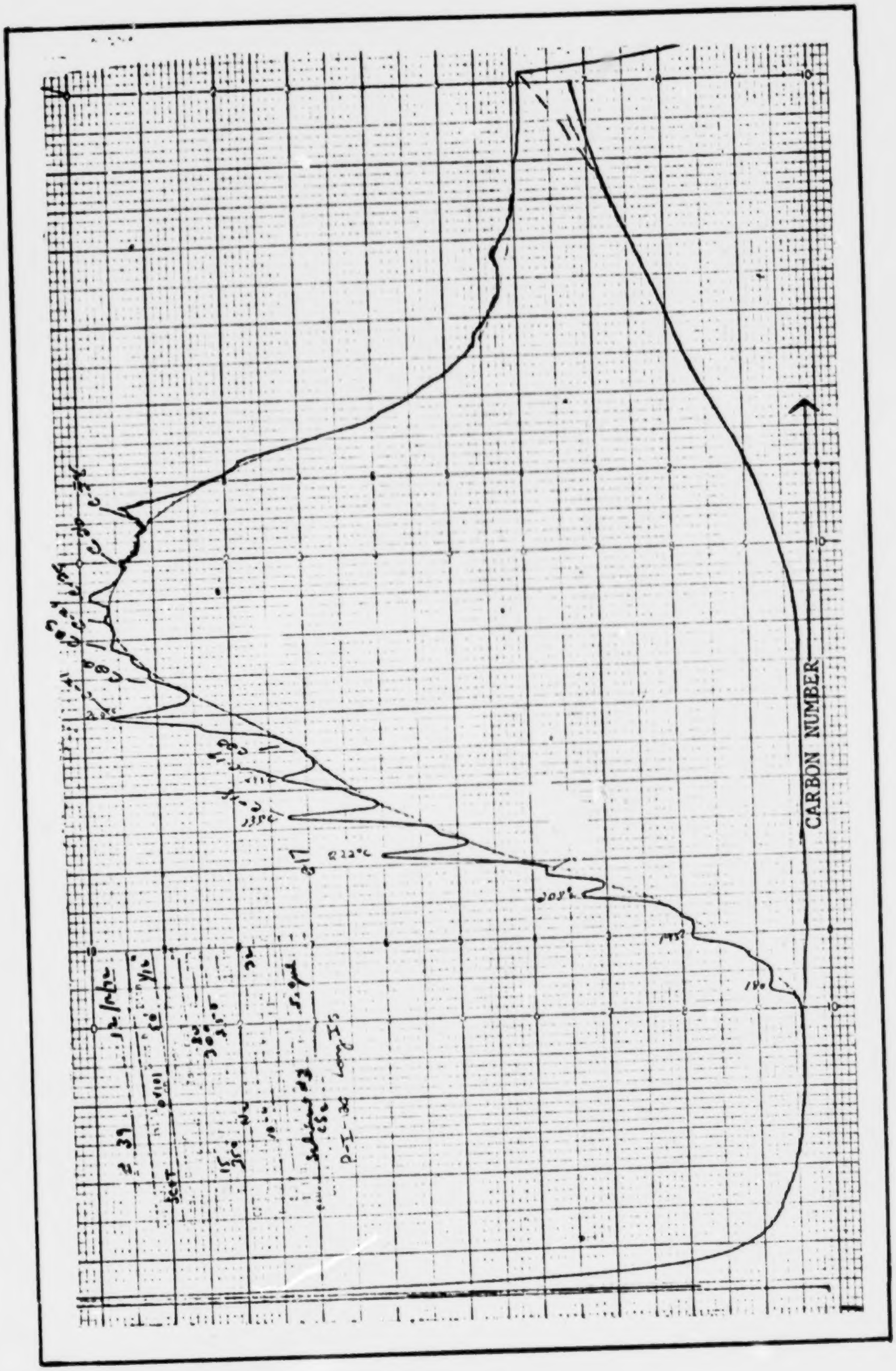


FIGURE 20

Chromatogram of Sediment
Long Island -- Survey I

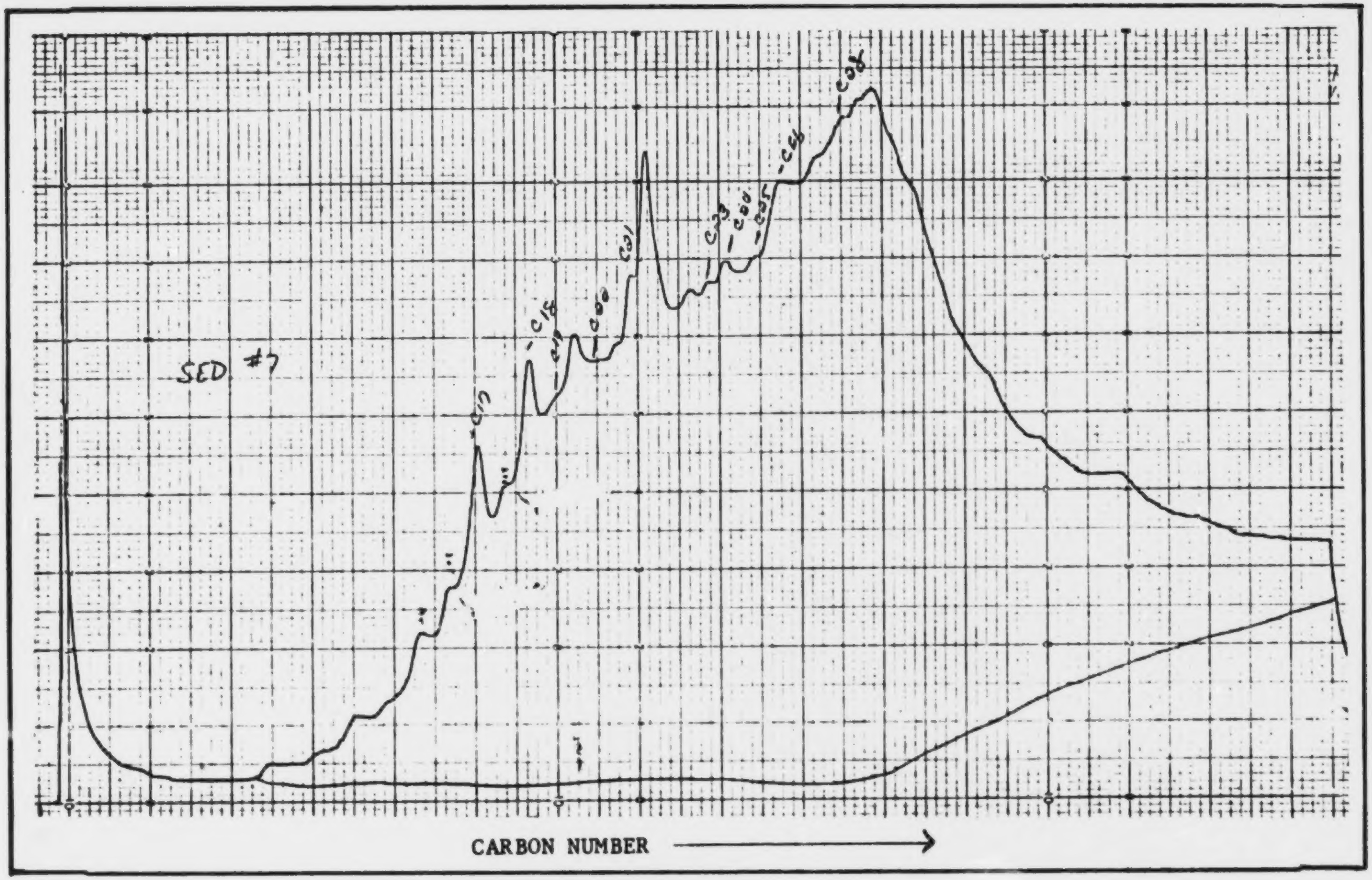


FIGURE 21

Chromatogram of Sediment
Long Island -- Survey II

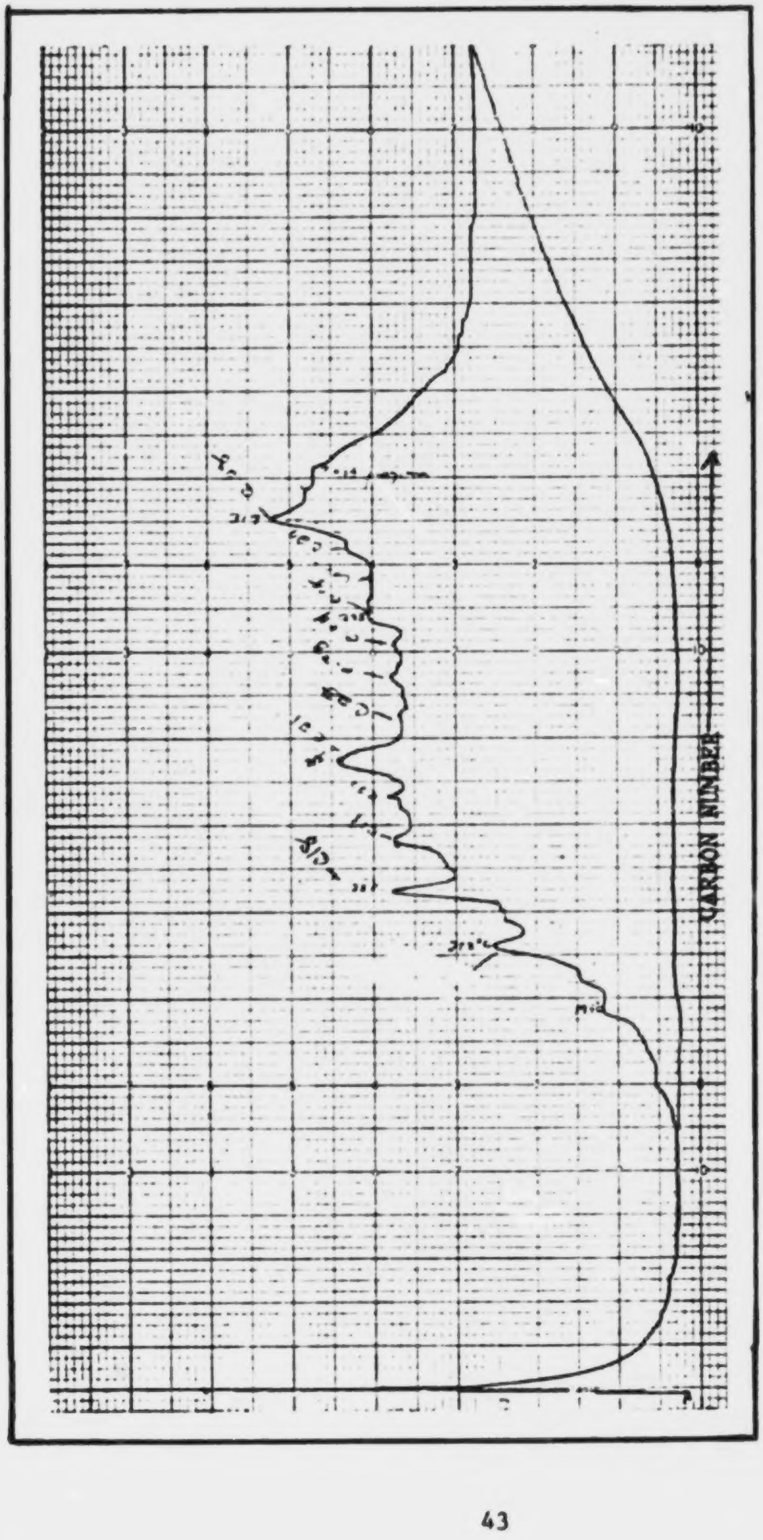


FIGURE 22

Chromatogram of Sediment
Long Island -- Survey III

TABLE 3

QUANTITATIVE HYDROCARBON ANALYSIS

SUBTIDAL STATIONS

SAMPLE	STATION	SURVEY	TOTAL HC MG/KG	INJECTED CONC. µG	RELATIVE ATTENUATION
Sediments	Long Island	I	66	329	32
		II	75	180	32
		III	53	140	32
Sediments	Bailey* Island	I	26	152	32
		III	29	113	32
Water	Long Island	I	0.3**	25	32
		III	0.7**	27.6	32
Water	Bailey* Island	I	0.2**	20	32
		III	0.4**	17.6	32
Lobster	Long Island	I	32	42.5	64
		II	70	18.6	64
		III	73	16.8	64
Lobster	Bailey* Island	II	29	7.7	64

* Control Stations

** Value is in mg per liter

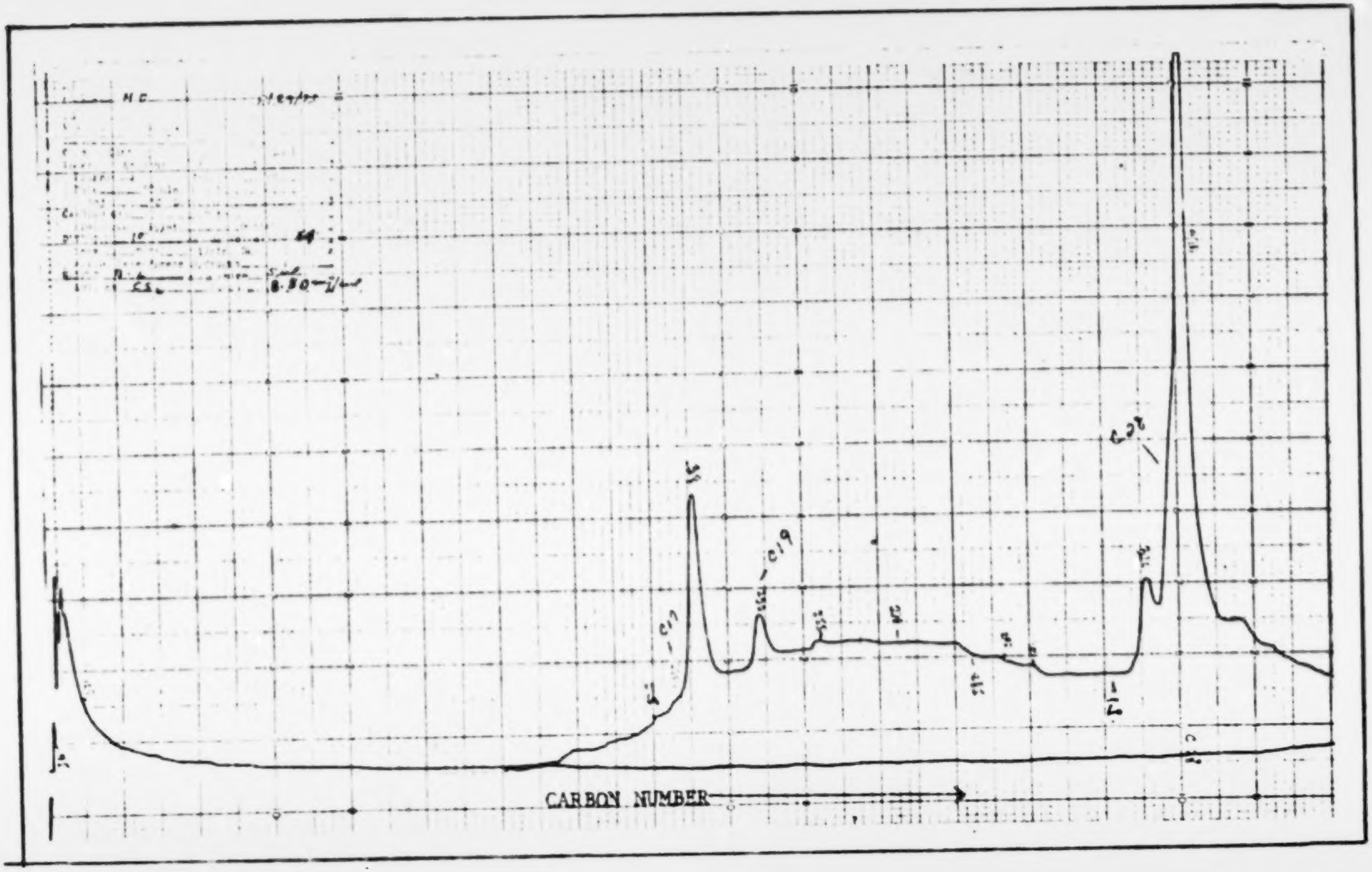


FIGURE 23

Chromatogram of Lobster (Homarus americanus)
Long Island -- Survey I

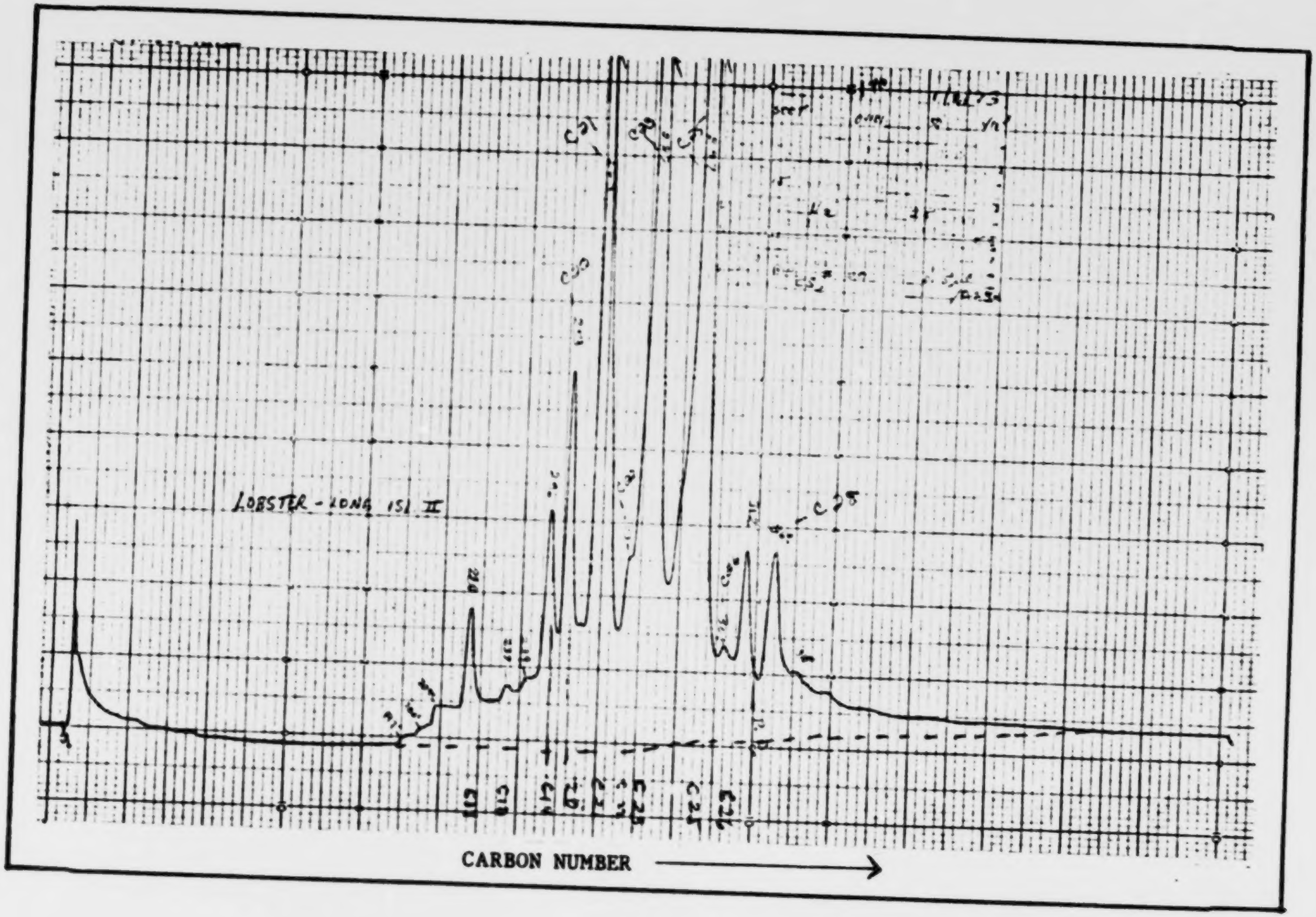


FIGURE 24

Chromatogram of Lobster (Homarus americanus)
Long Island -- Survey II

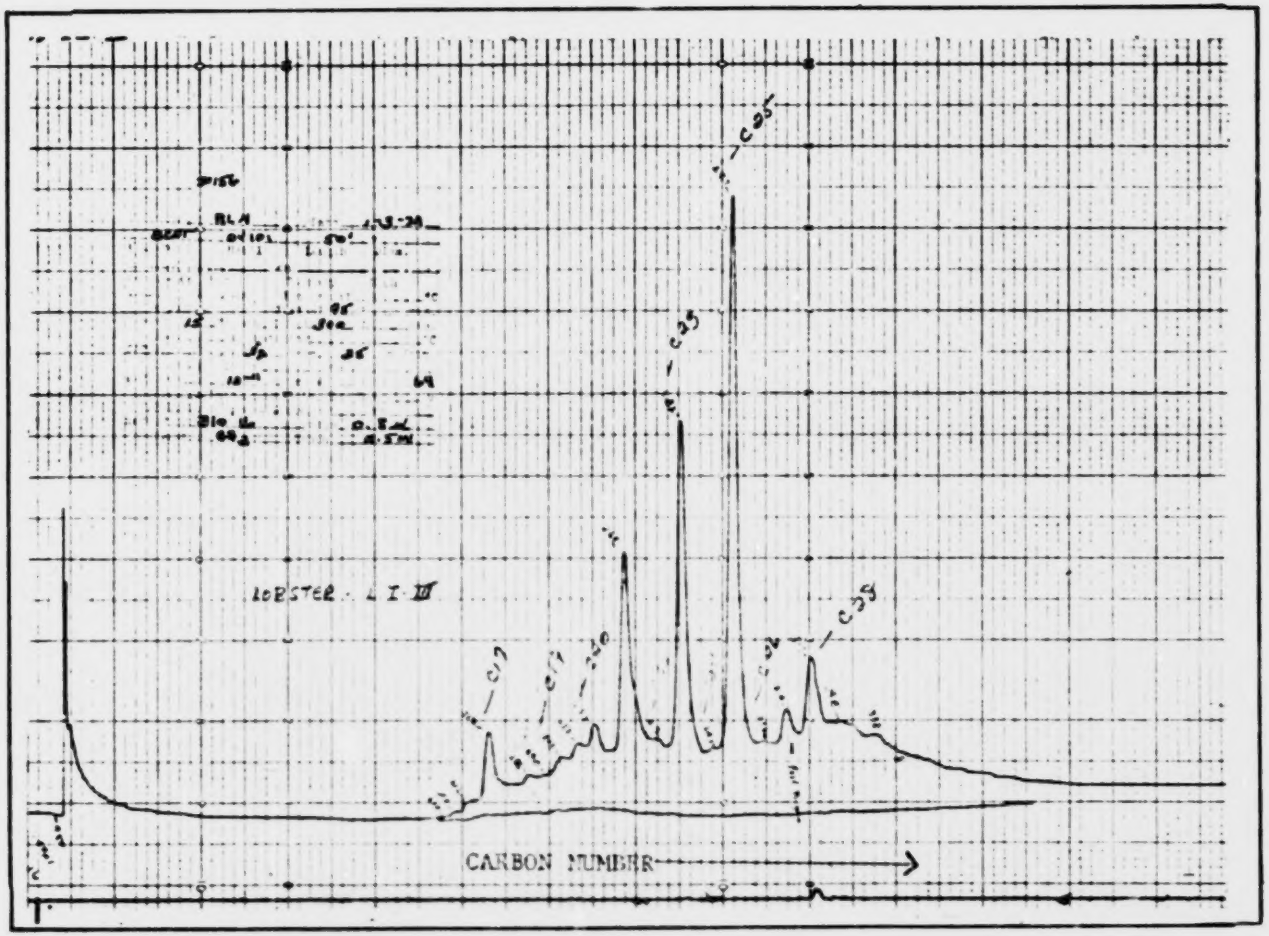


FIGURE 25

Chromatogram of Lobster (Homarus americanus)
Long Island -- Survey III

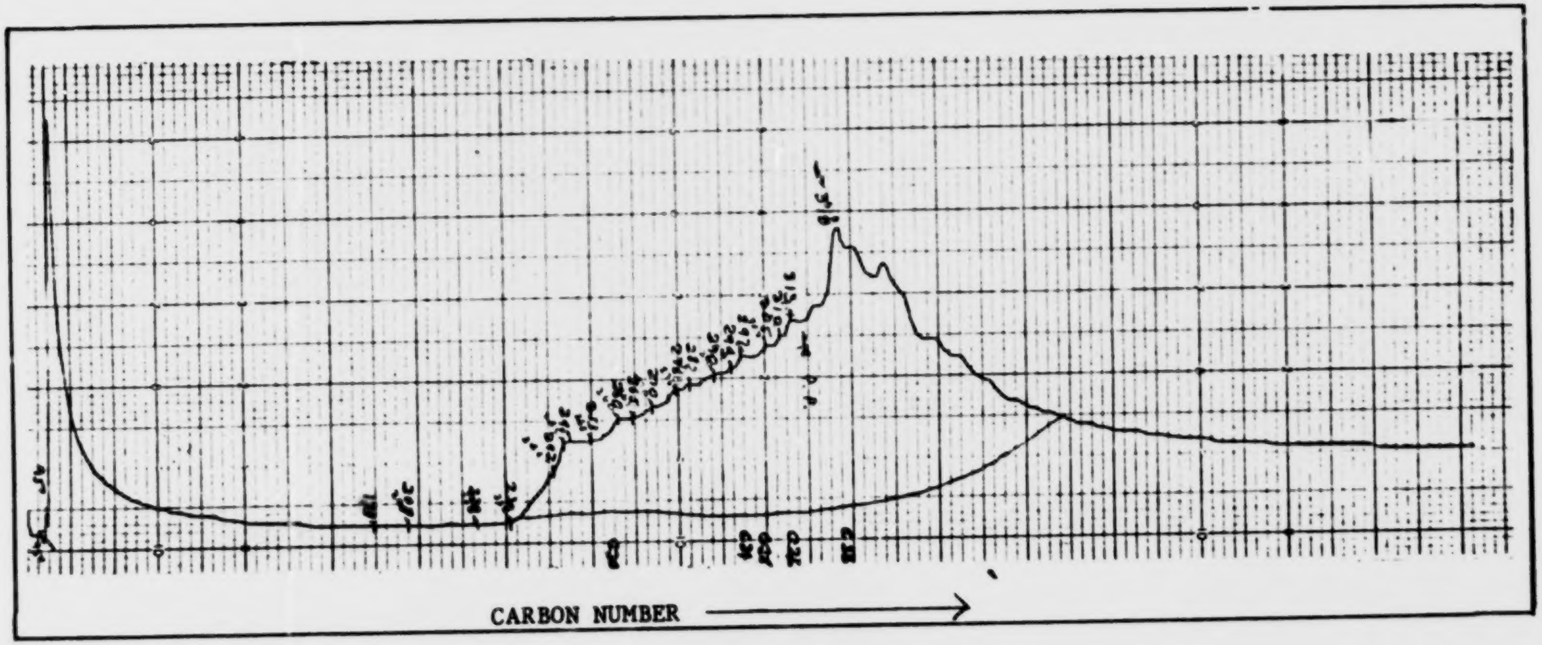


FIGURE 26

Chromatogram of Water
Long Island -- Survey I

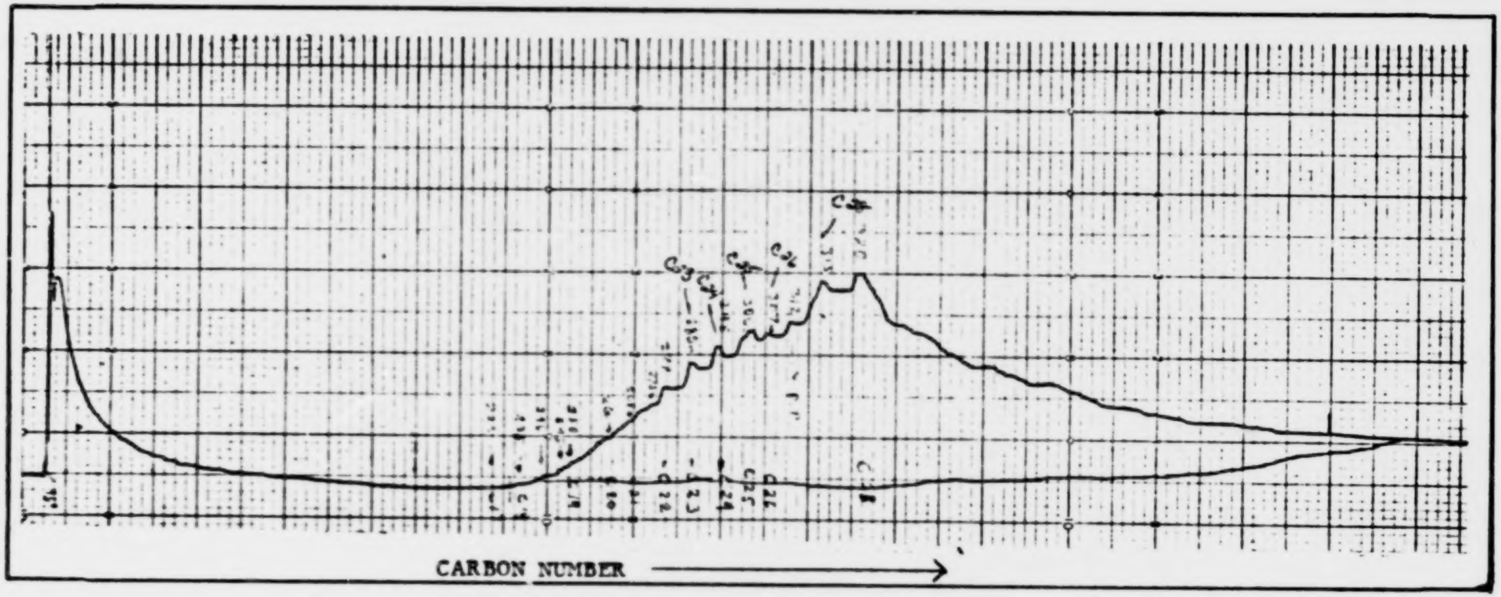


FIGURE 27

Chromatogram of Water
Long Island -- Survey III

There was no evidence of the oil during Survey II (Figure 29), but the sediment samples were taken further offshore than in Survey I, beyond a natural sill. By Survey III, the same offshore area had become contaminated with weathered oil (Figure 30).

Although a profile of possibly weathered fuel oil was present in lobsters from the control area (Bailey Island) during Survey II (Figure 31), the total hydrocarbon in the control lobsters was very low (29 mg/kg), indicating little or no build-up of a residual pool of aromatics of cycloalkanes.

Water flushing this station contained little oil during the first survey, but did show a characteristic envelope during Survey III (Figures 32 and 33) suggesting that the contamination of the area during Survey I occurred by sediment transport by strong tidal currents against the prevailing non-tidal drift. Counter-current transport upstream along the bottom is not unusual in the marine environment.

Rocky Intertidal Areas:

The Littorina at the sloping rock station at Cow Island during Survey I were heavily contaminated with oil (Figure 34). By Survey II, the total concentration of hydrocarbons in Littorina tissues had not diminished (Table 4 and Figure 35). On Survey III, the total concentration of hydrocarbon dropped from about 245 mg/kg wet wt to about 35 mg, but a pattern of weathered oil was still present (Figure 36). On the same survey, Littorina at the Long Island station contained nearly twice the hydrocarbon concentration of those at Cow Island (Table 4 and Figure 37). The profile for Littorina from Bailey Island (control station) during Survey III could not be positively identified (Figure 38).

The dog whelk, Thais, was not abundant until Survey II. Collected from Long Island, it then contained 128 mg hydrocarbon per kg wet wt with a definite oil component (Figure 39, Table 4). By Survey III, the total hydrocarbon had increased to 884 mg/kg wet wt and the aromatic cycloalkane portion appeared to increase while the lower boilers and paraffin peaks were truncated (Figure 40).

The Fucus zone on the rocky intertidal station at Long Island was within the tidal range heavily coated by the oil, such that the weight of oil was twelve-and-a-half to thirteen-and-a-half percent the weight of the Fucus, peaking on the second survey (Table 4). By Survey III, the oil had washed away considerably (Figure 41). At the control station (Figure 42), there was some contamination, but the total

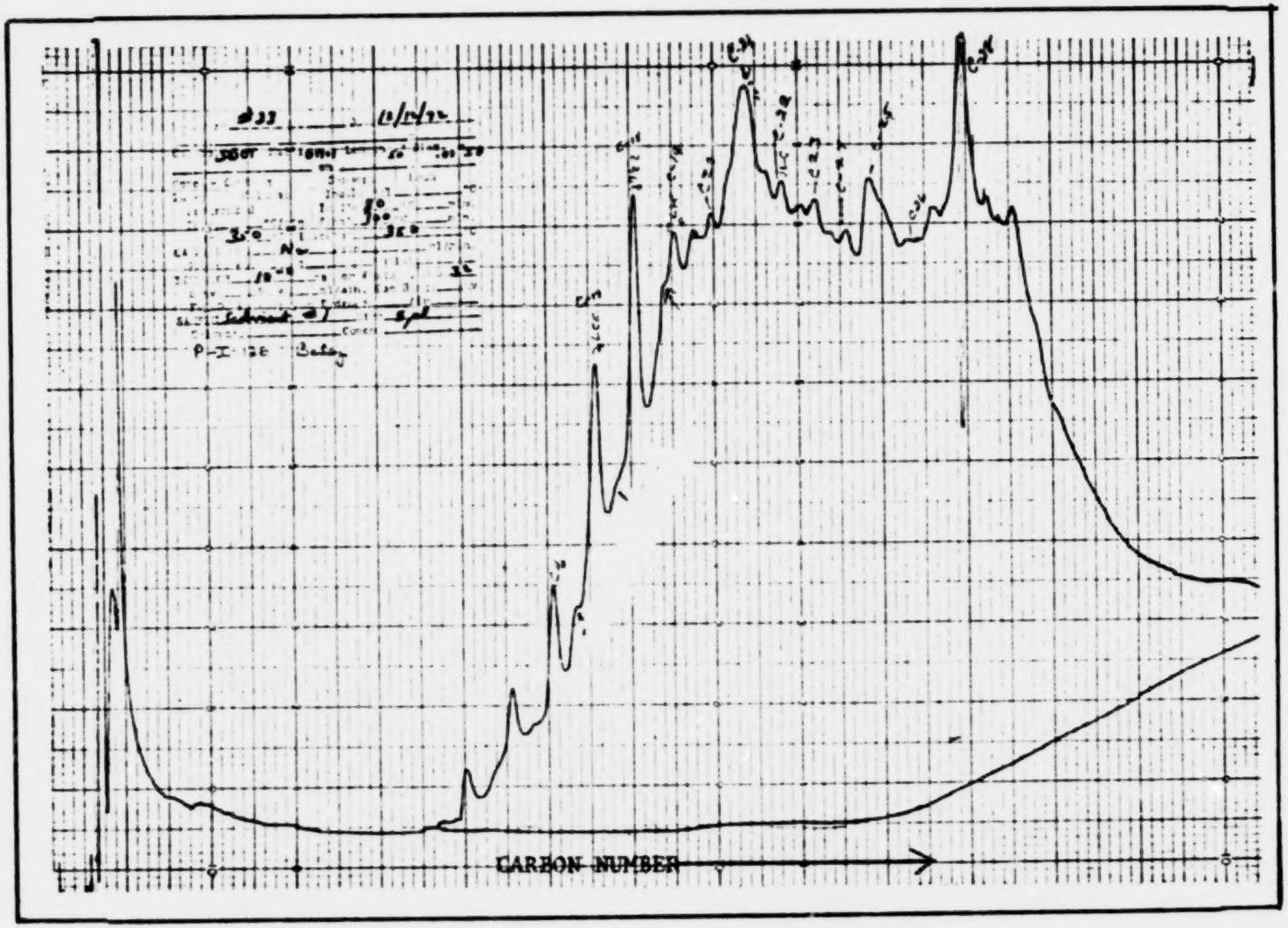


FIGURE 28

Chromatogram of Sediments
Bailey Island -- Survey I

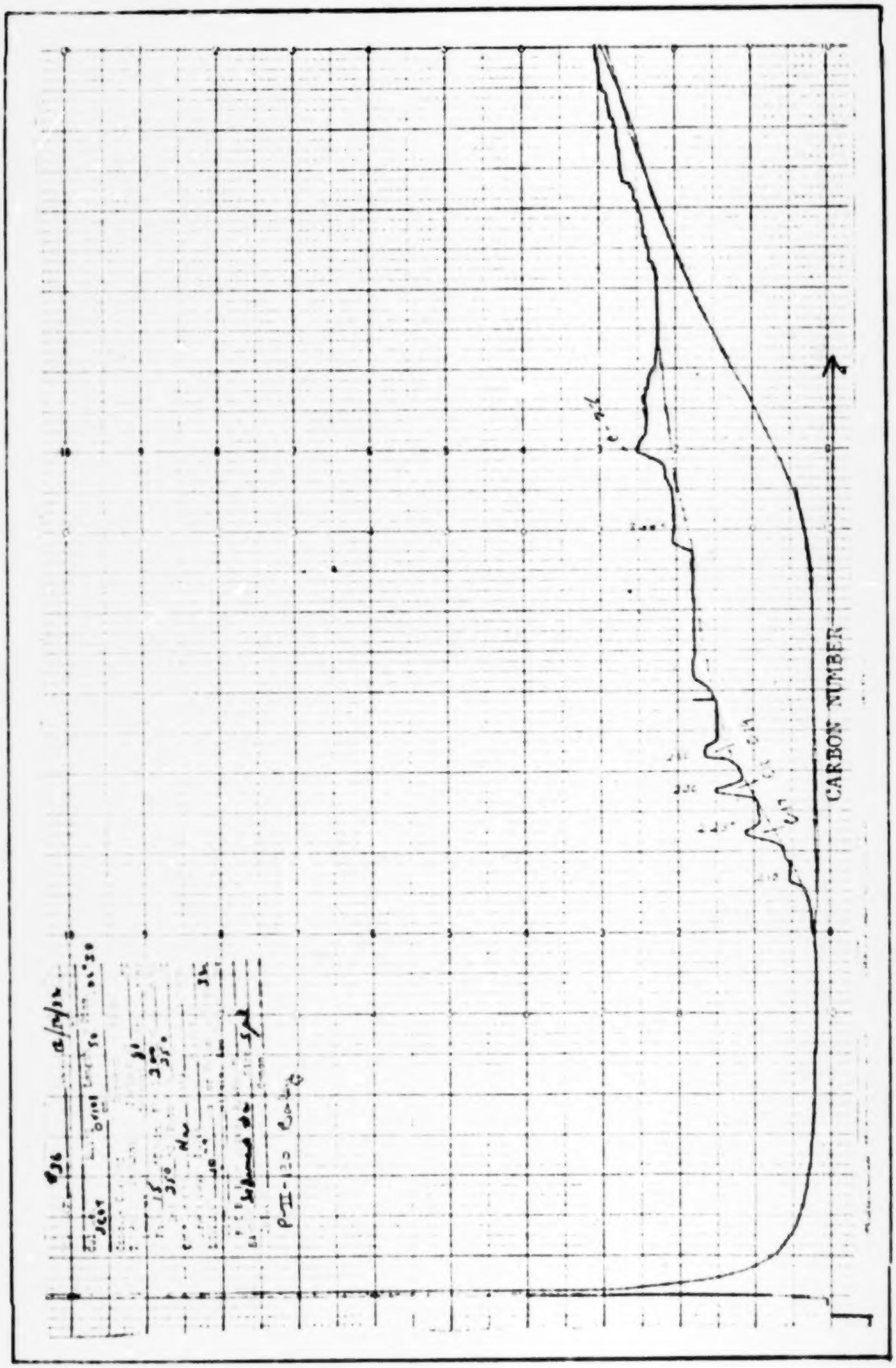


FIGURE 29

Chromatogram of Sediments
Bailey Island -- Survey II

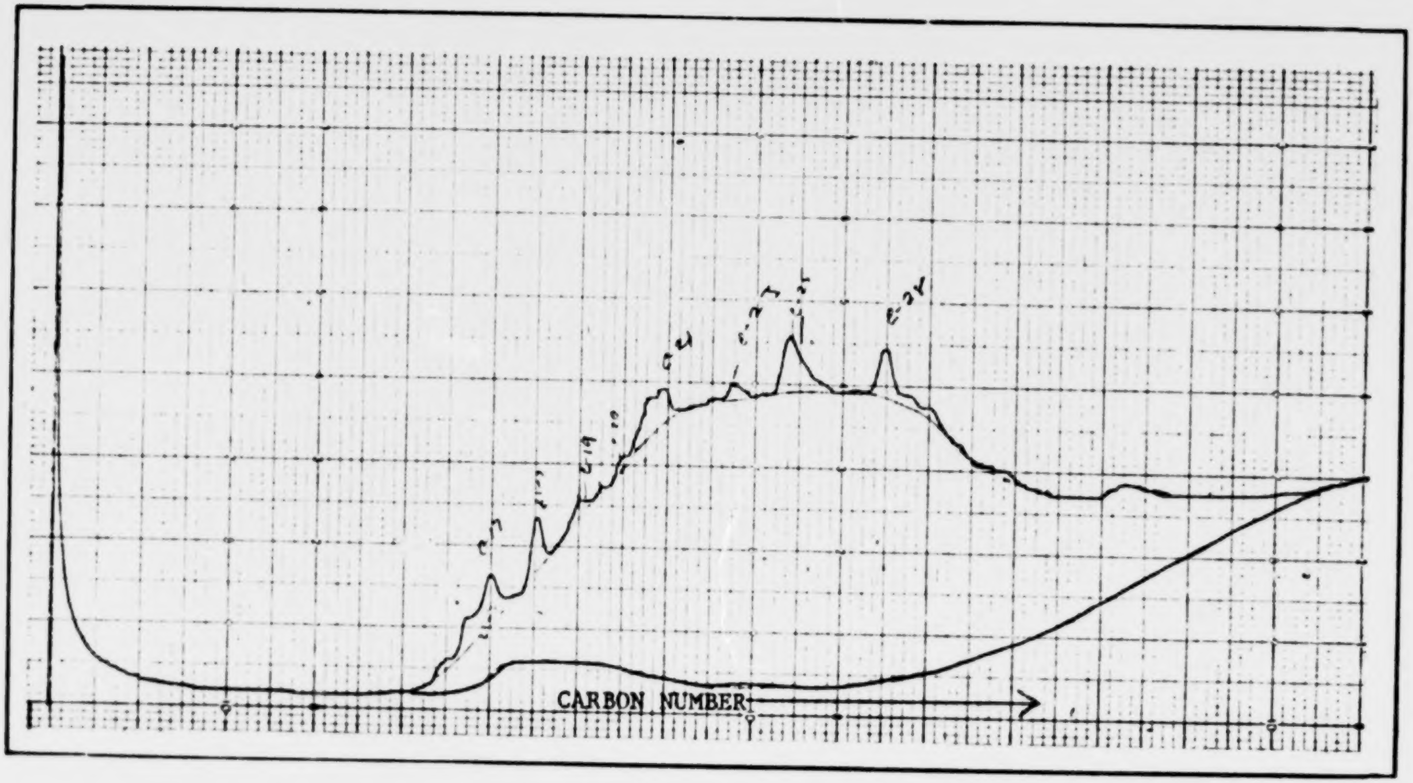


FIGURE 30

Chromatogram of Sediments
Bailey Island -- Survey III

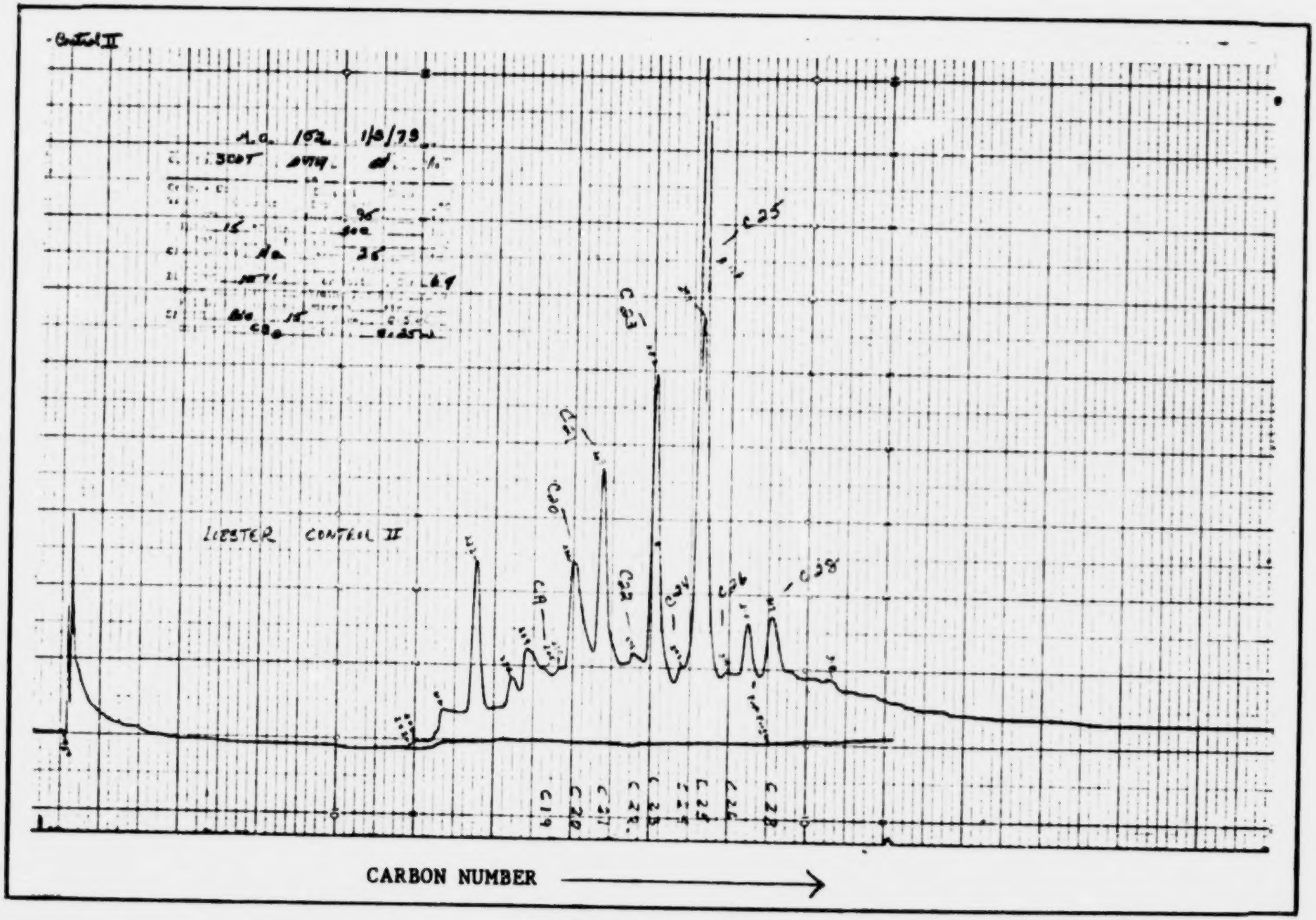


FIGURE 31

Chromatogram of Lobster (Homarus americanus)
Bailey Island -- Survey II

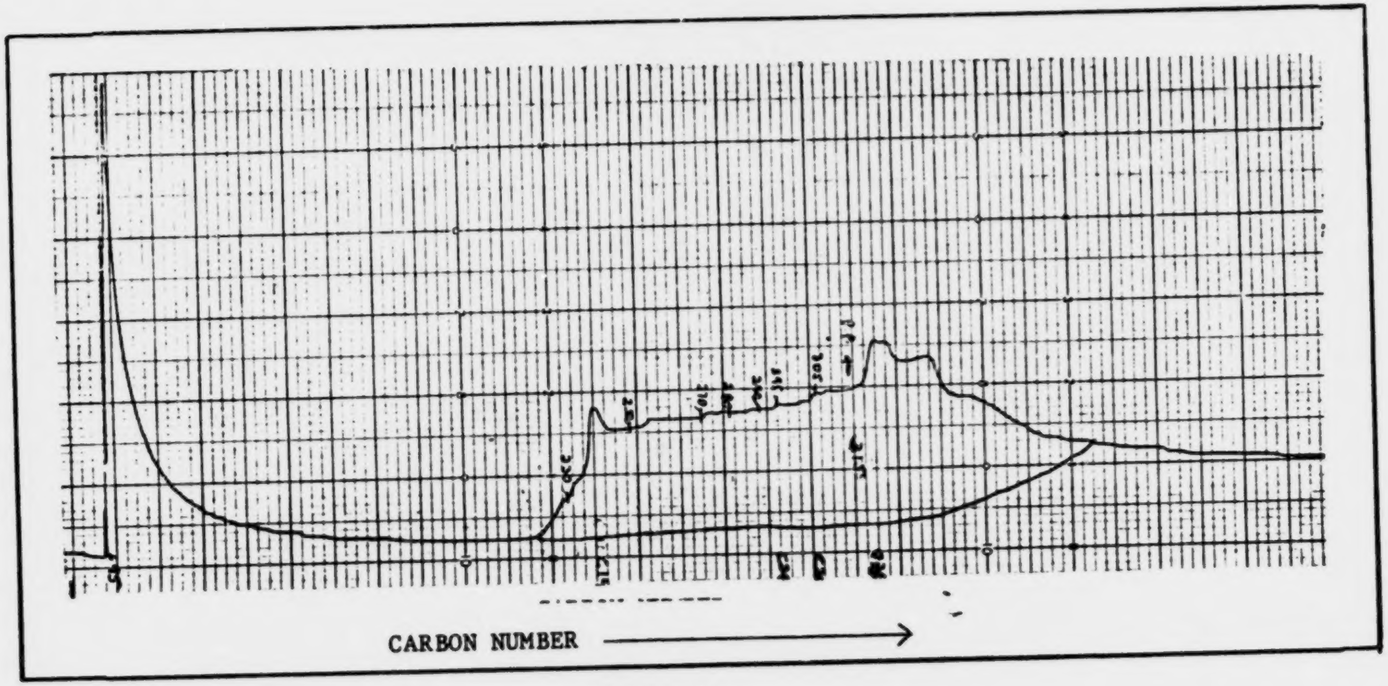


FIGURE 32

Chromatogram of Water
Bailey Island -- Survey I

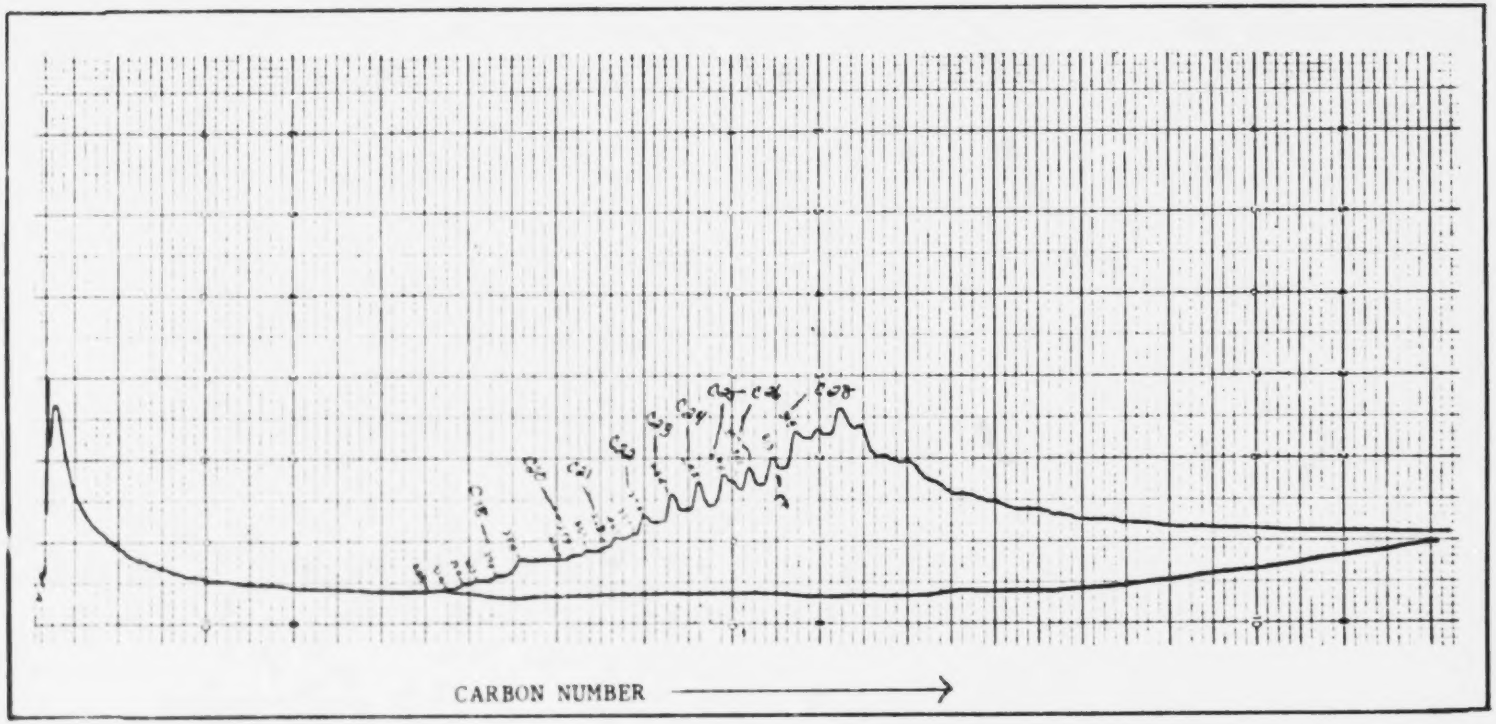


FIGURE 33

Chromatogram of Water
Bailey Island -- Survey III

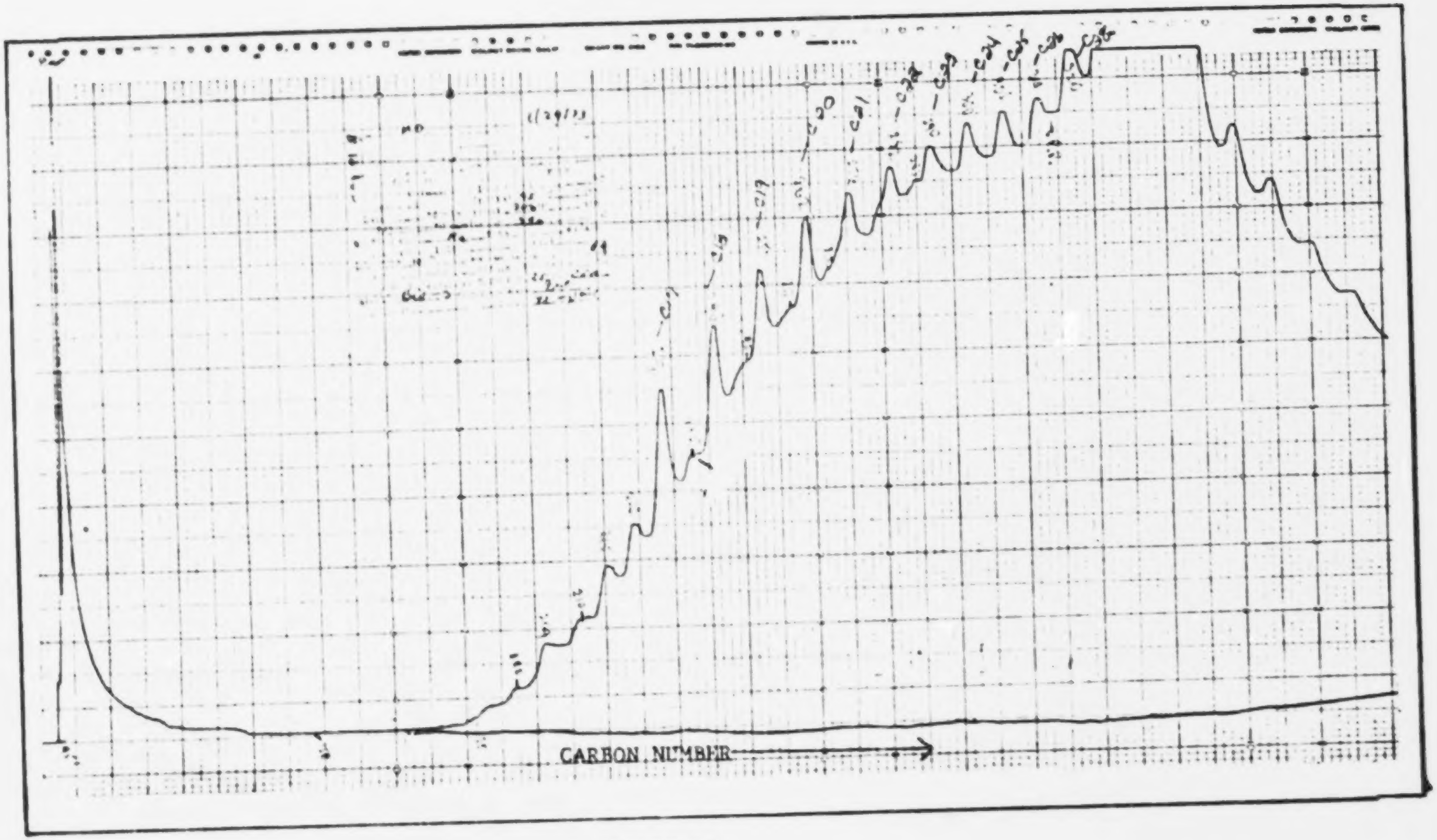


FIGURE 34

Chromatogram of Periwinkles (Littorina littorea)
Cow Island -- Survey I

TABLE 4

QUANTITATIVE HYDROCARBON ANALYSIS

ROCKY INTERTIDAL STATIONS

SAMPLE	STATION	SURVEY	TOTAL HC MG/KG	INJECTED HC µG	RELATIVE ATTENUATION
Littorina	Cow Island	I	244	472.7	64
		II	245	61.2	64
		III	35	32.8	32
	Long Island	III	63	8.5	64
	Bailey Island*	III	82	16.9	32
Thais	Long Island	II	128	32.4	64
		III	884	80	64
	Bailey Island*	III	122	15.6	8
Fucus	Long Island	I	124,800	--	—
		II	135,000	--	—
		III	1,890	358.4	64
	Bailey Island*	II	500	14.9	32
Ascophyllum	Cow Island	I	104,000	--	--
		II	56	23.4	--
		III	365	38.9	32
	Bailey Island*	II	400	32.2	64

* Control

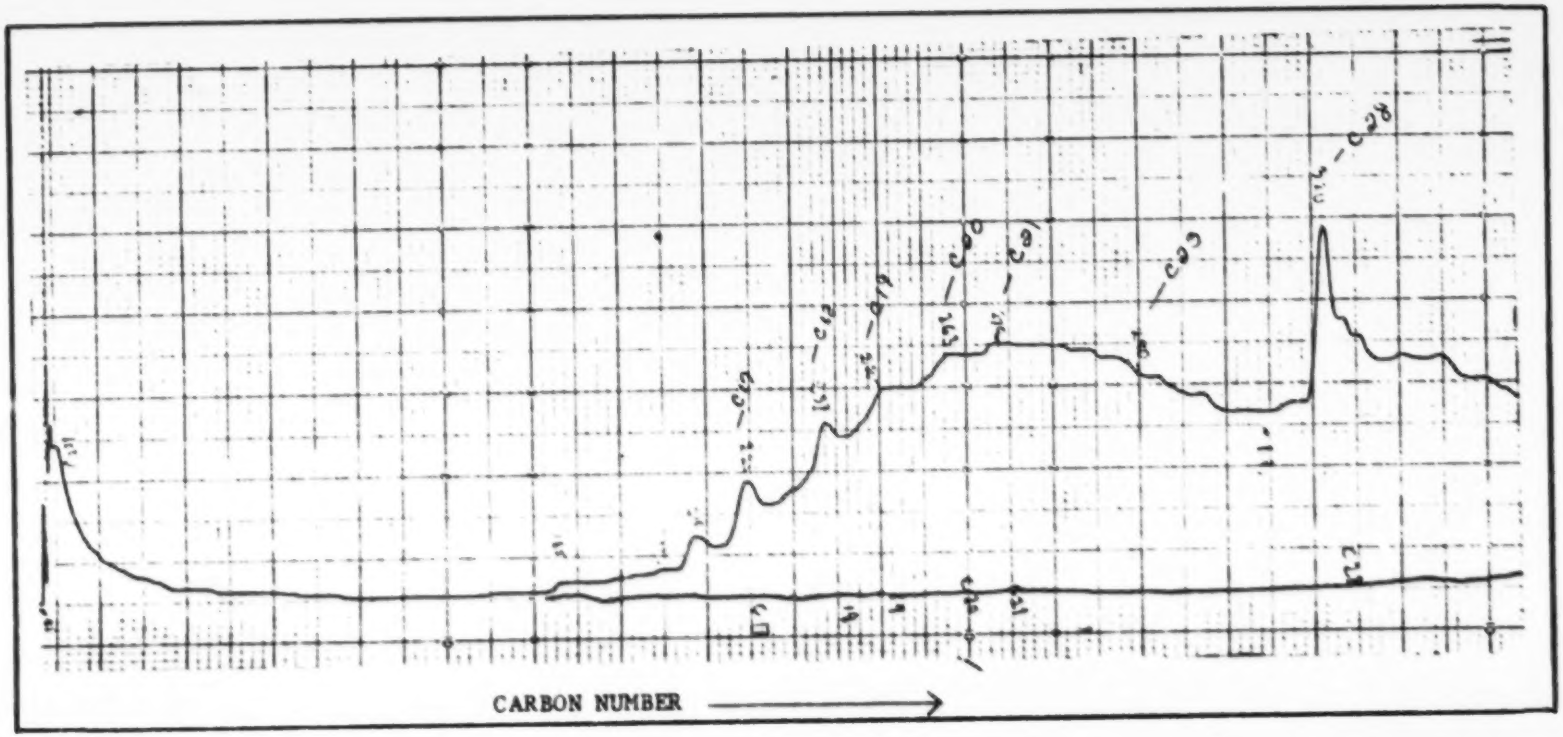


FIGURE 35

Chromatogram of Periwinkles (Littorina littorea)
Cow Island -- Survey II

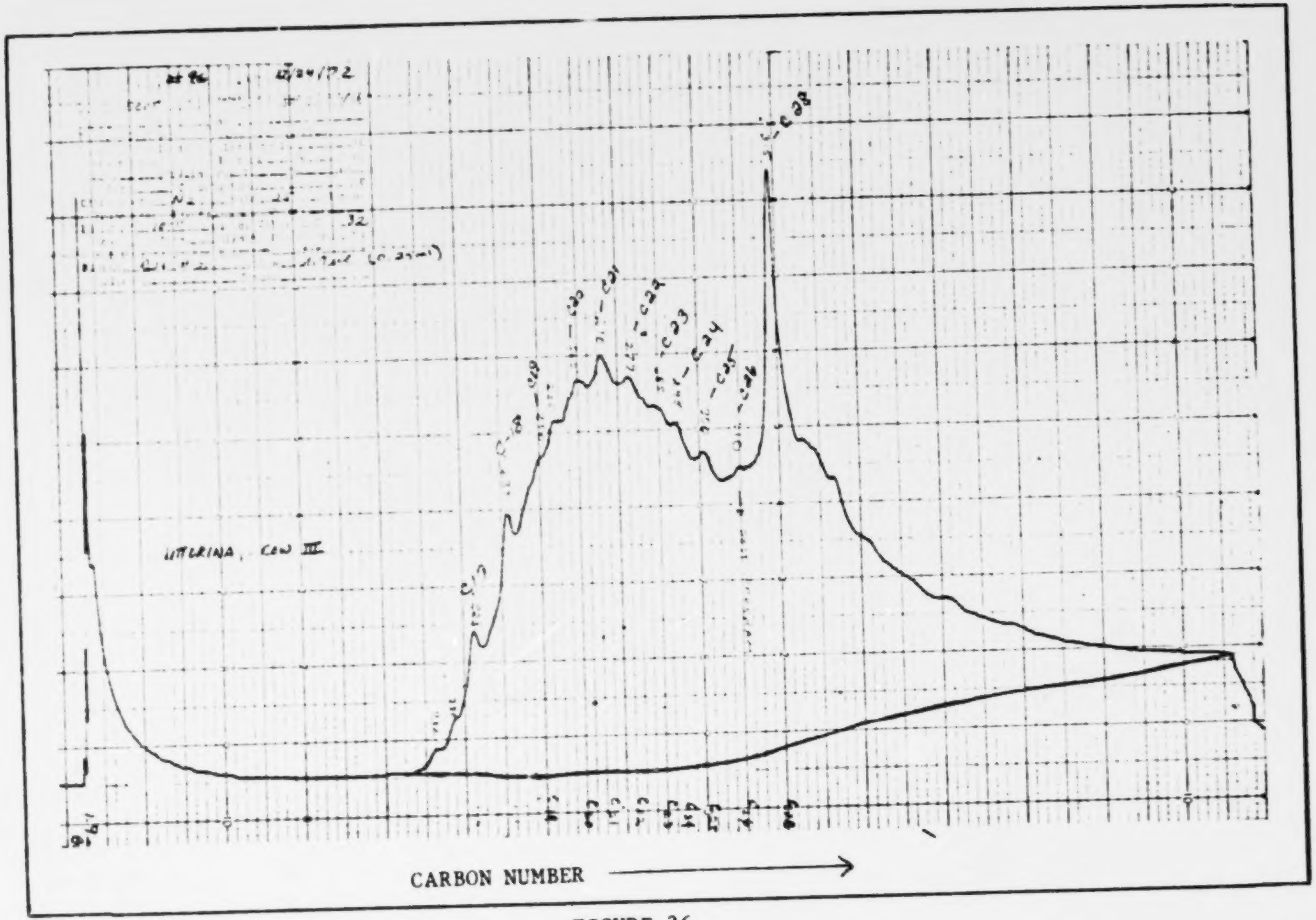


FIGURE 36

Chromatogram of Periwinkles (Littorina littorea)
Cow Island -- Survey III

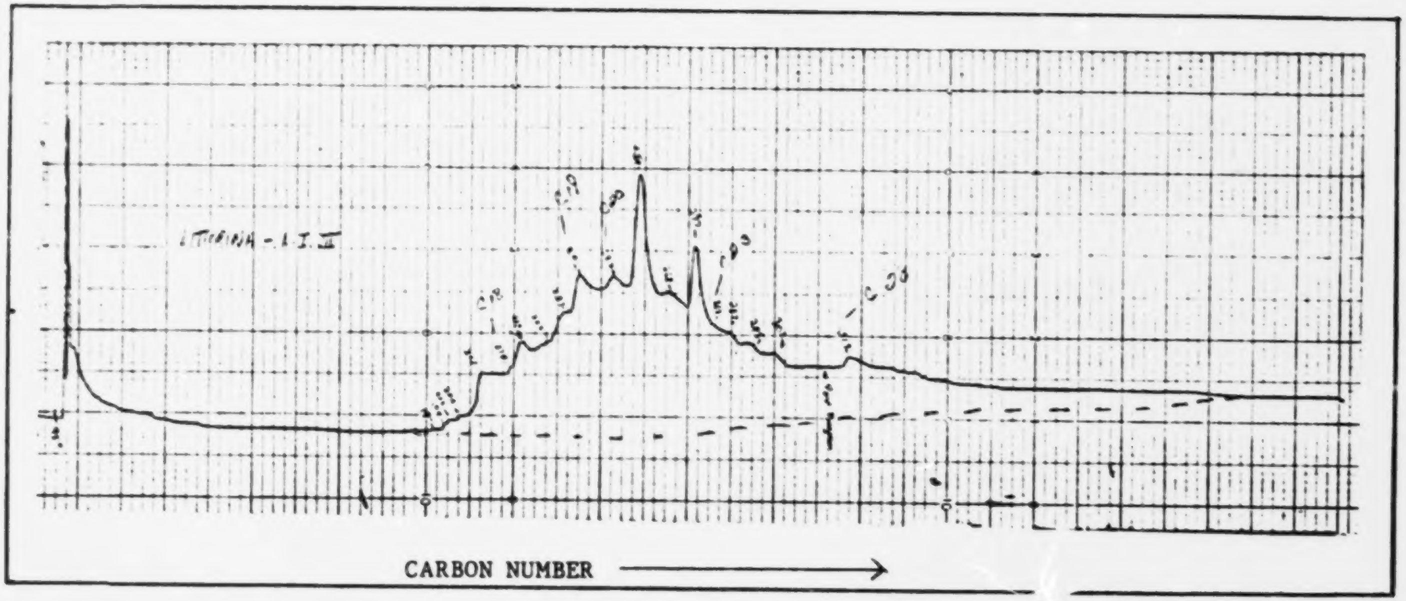


FIGURE 37

Chromatogram of Periwinkles (Littorina littorea)
Long Island -- Survey III

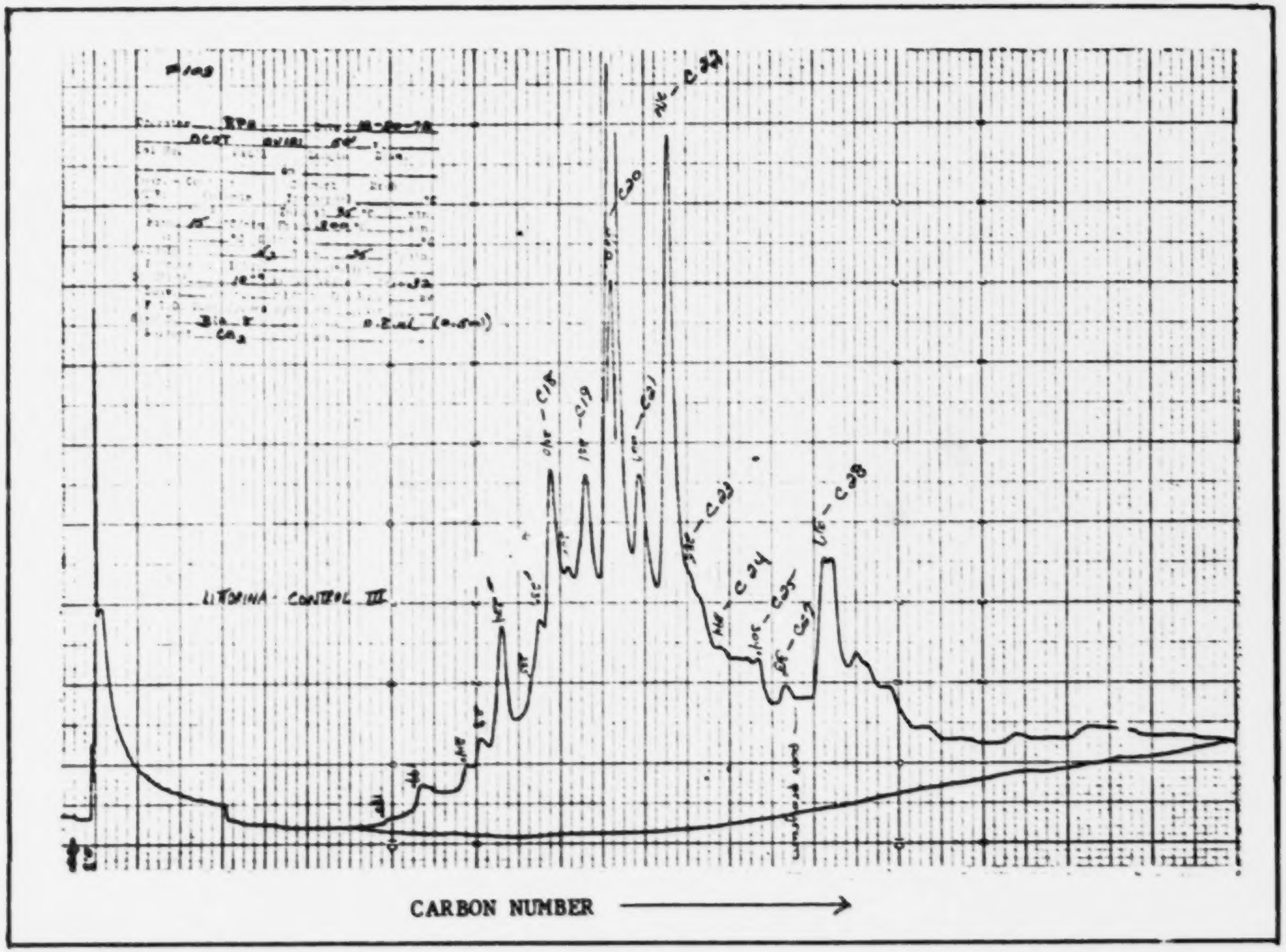


FIGURE 38

Chromatogram of Periwinkles (Littorina littorea)
Bailey Island -- Survey III

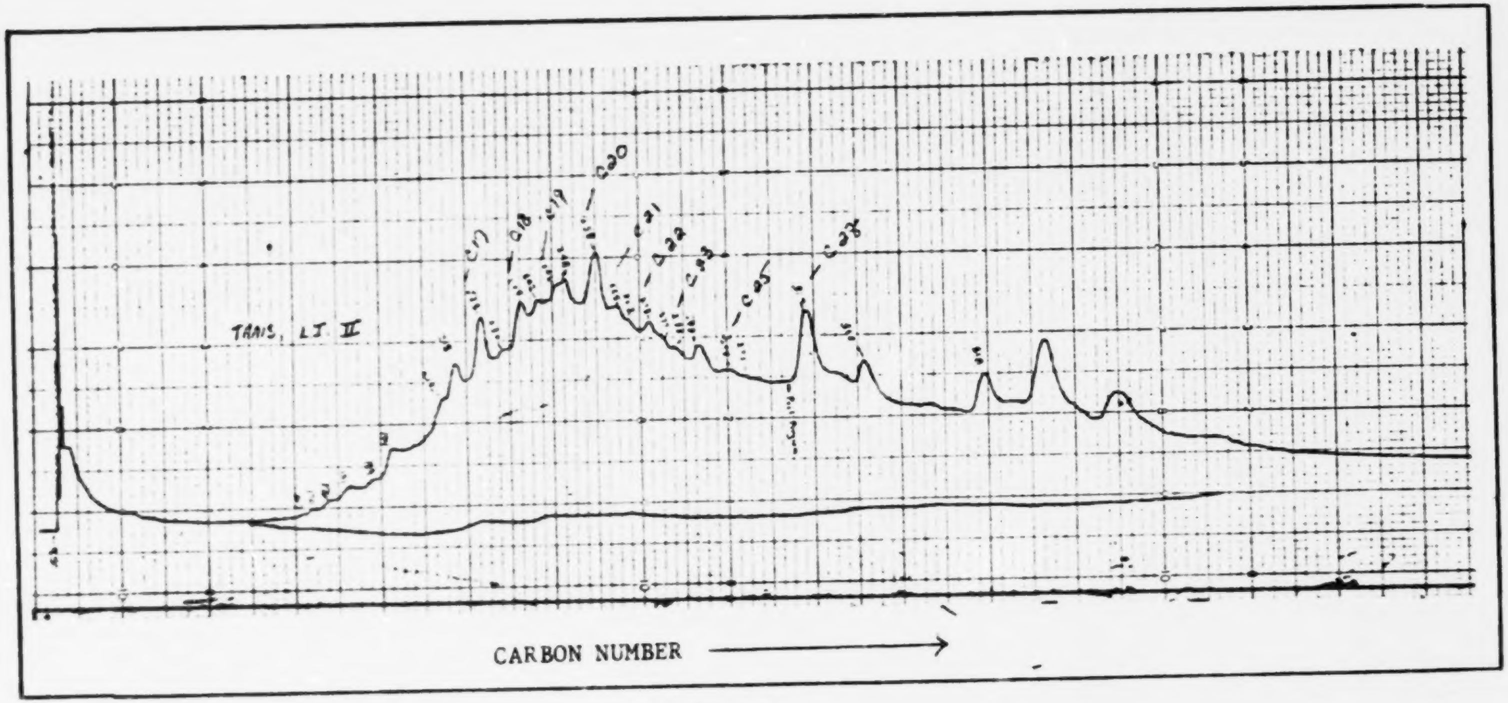


FIGURE 39

Chromatogram of Dog Whelks (Thais lapillus)
Long Island -- Survey II

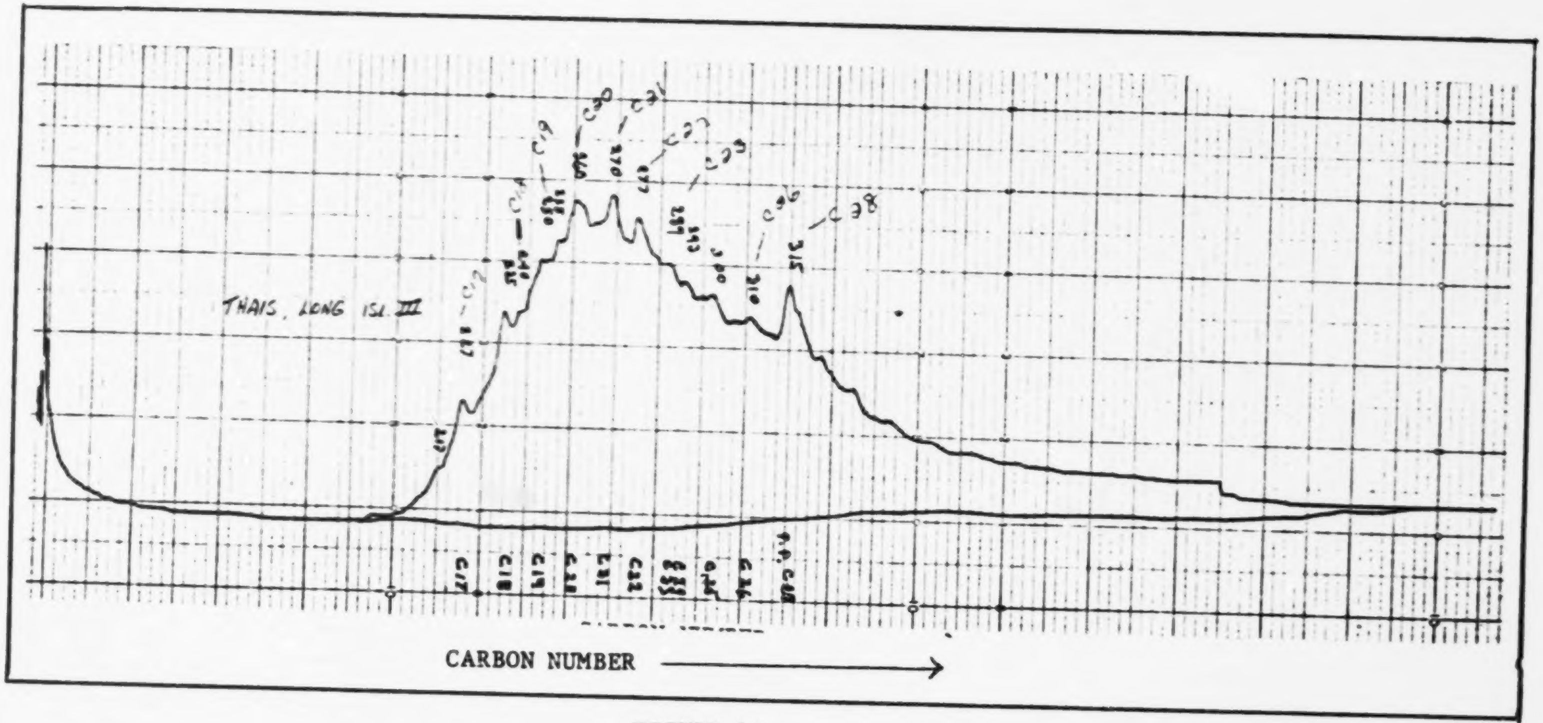


FIGURE 40

Chromatogram of Dog Whelks (Thais lapillus)
Long Island -- Survey III

hydrocarbon content was far less than that of the Long Island station.

Ascophyllum, attached below the heavily coated zone at Cow Island, was heavily contaminated for the first survey (Table 4), but apparently this was surface contamination because by Survey II there was no distinctive evidence for the oil (Figure 43). By Survey III, contamination was present at relatively low levels compared with Survey I (Figure 44). Ascophyllum from the control station (Bailey Island) showed some contamination (Figure 45).

Water Column:

In addition to the water samples taken at the benthic stations and intertidal mud flats, water from the middle portion of Hussey Sound at one foot below the surface and at 30 feet below the surface was analyzed for oil. During both Survey I and Survey III, there was oil present in measurable quantities both at the one foot level and at mid-depth. The mid-depth concentrations were four times those at the subsurface during Survey I and about one-and-a-third times the subsurface concentration during Survey III (Table 5). The peaks of the chromatographic profile during Survey at the mid-depth level were relatively well differentiated, suggesting that fine droplets of the whole oil mixture on the surface may become suspended and mixed through the water column (Figures 46 and 47).

Beach Stations:

The total hydrocarbon for the surface sand (0-10 cm) and sand at depth (20-30 cm) are given in Table 6. The mid-depth 10-20 cm was found to contain a marked delineation between sand visibly oiled and that not visibly oiled at about 15 cm, so that analysis of the mixed sample would be misleading. The results of 0-10 cm were, therefore, considered representative of the 0-15 cm level and those from 20-30 cm were representative of 15-30 cm.

During the first survey, the oil was heavily concentrated in the top 15 cm of sand (43,200 mg/kg dry wt), while very little had leached to the lower level (15 mg/kg dry wt). By Survey II, the oil in the surface layer had decreased by one-third, but the concentrations at depth had increased 25 times to 380 mg/kg dry wt. This concentration was still only 1.3% that of the surface layers.

Survey III was conducted after the beach removal operations. On 16 September, 1972, the top six inches was removed from the

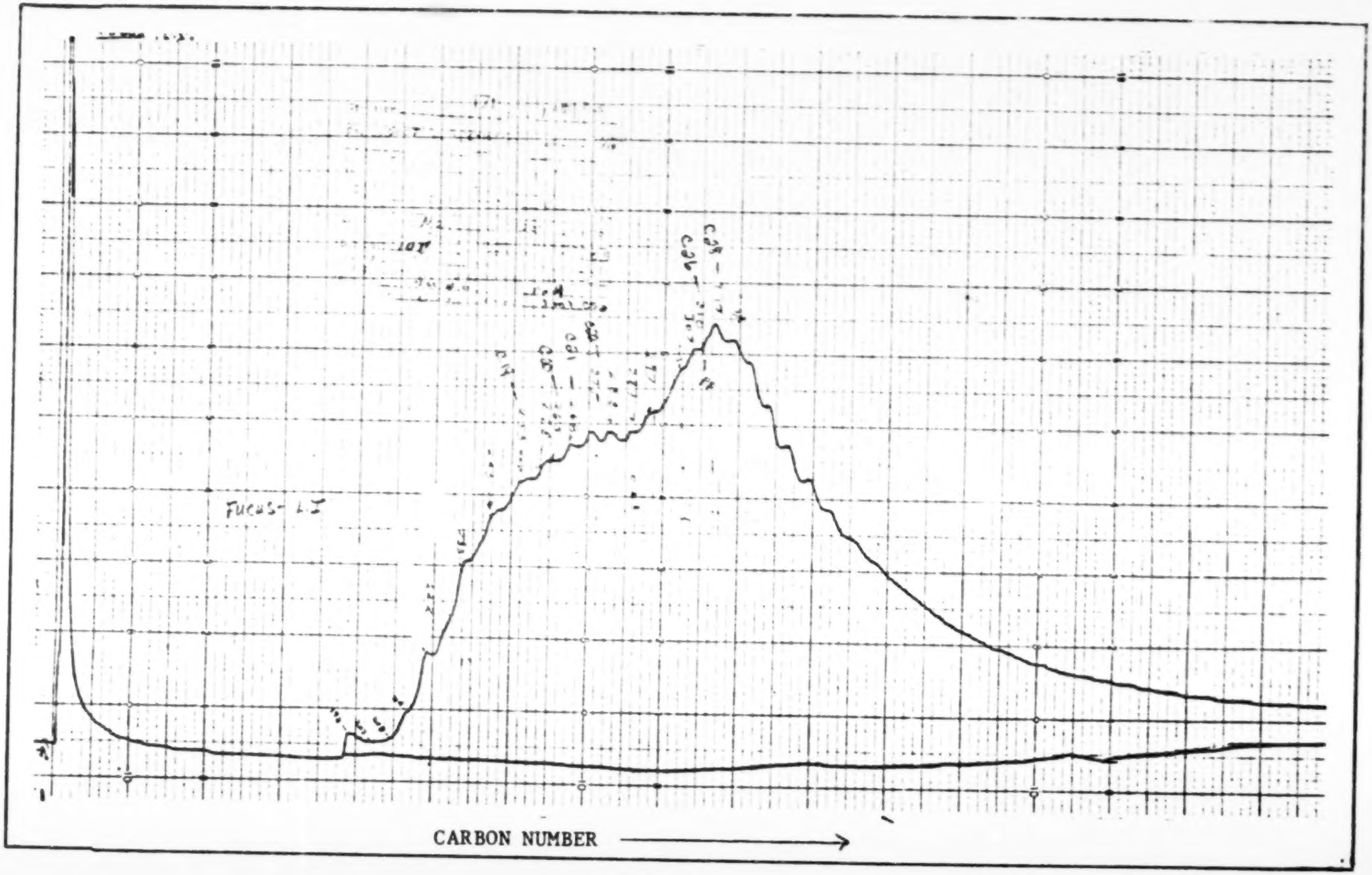


FIGURE 41

Chromatogram of Fucus
Long Island -- Survey III

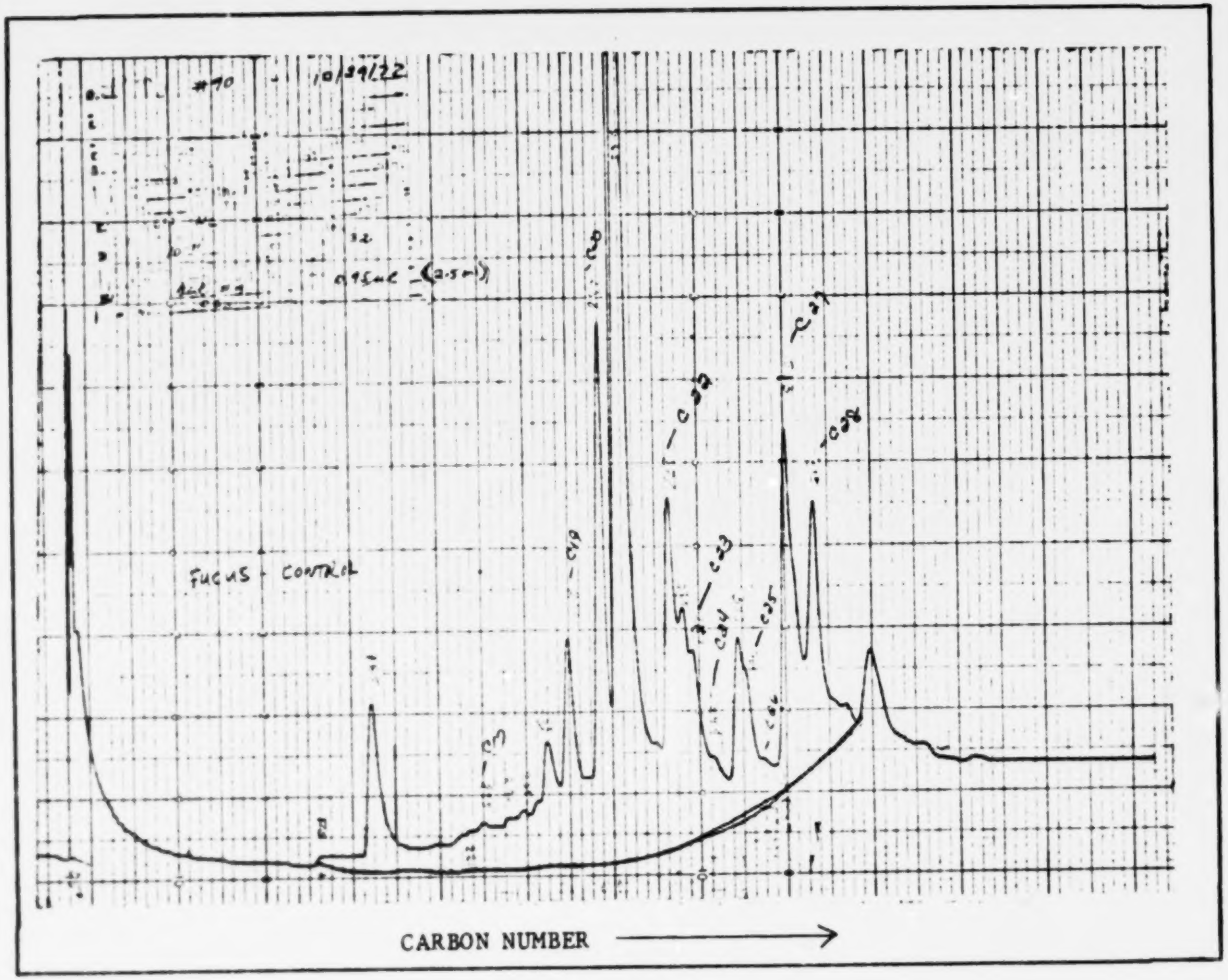


FIGURE 42

Chromatogram of Fucus
Bailey Island -- Survey II

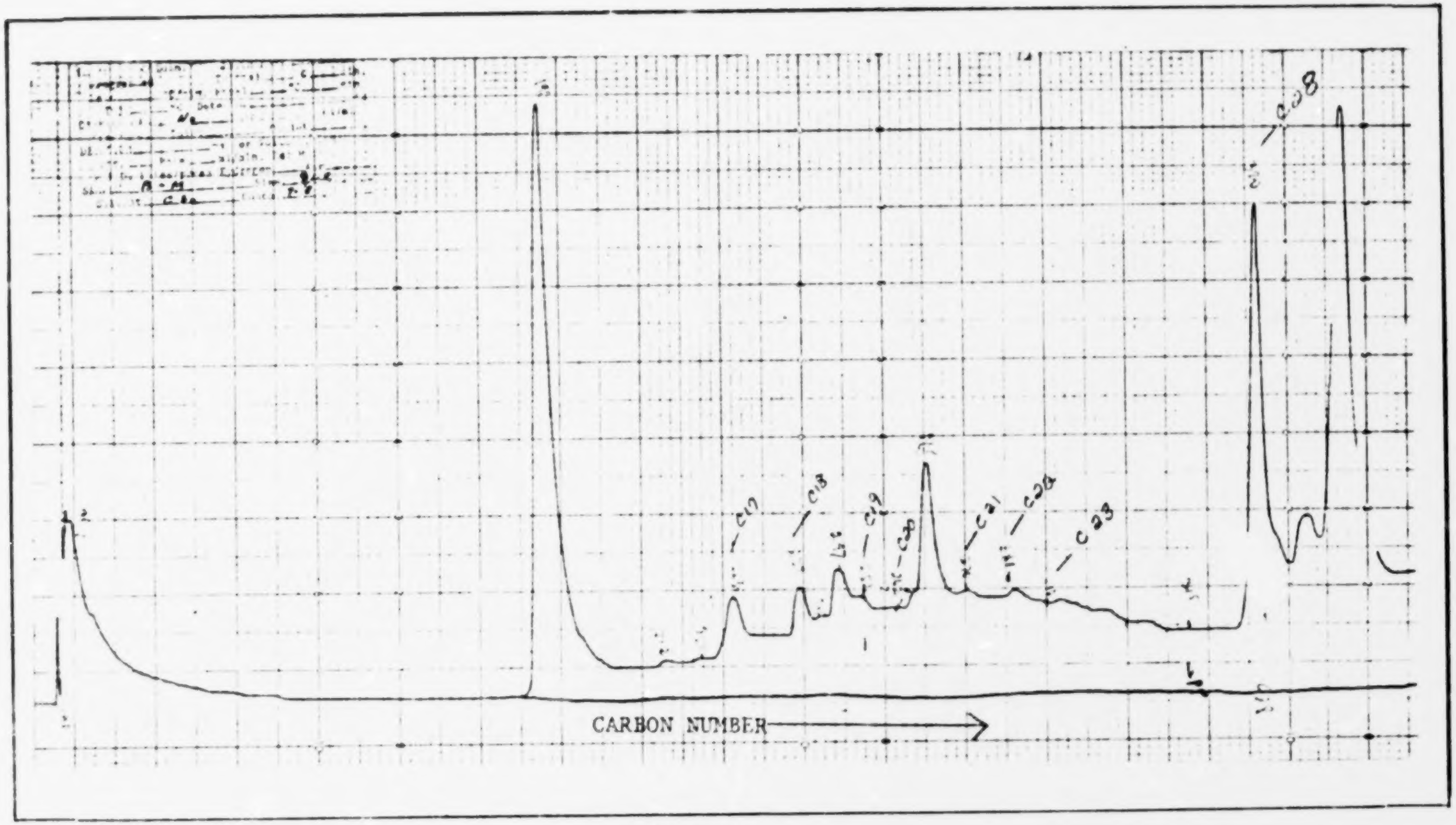


FIGURE 43

Chromatogram of Ascophyllum
Cow Island -- Survey II

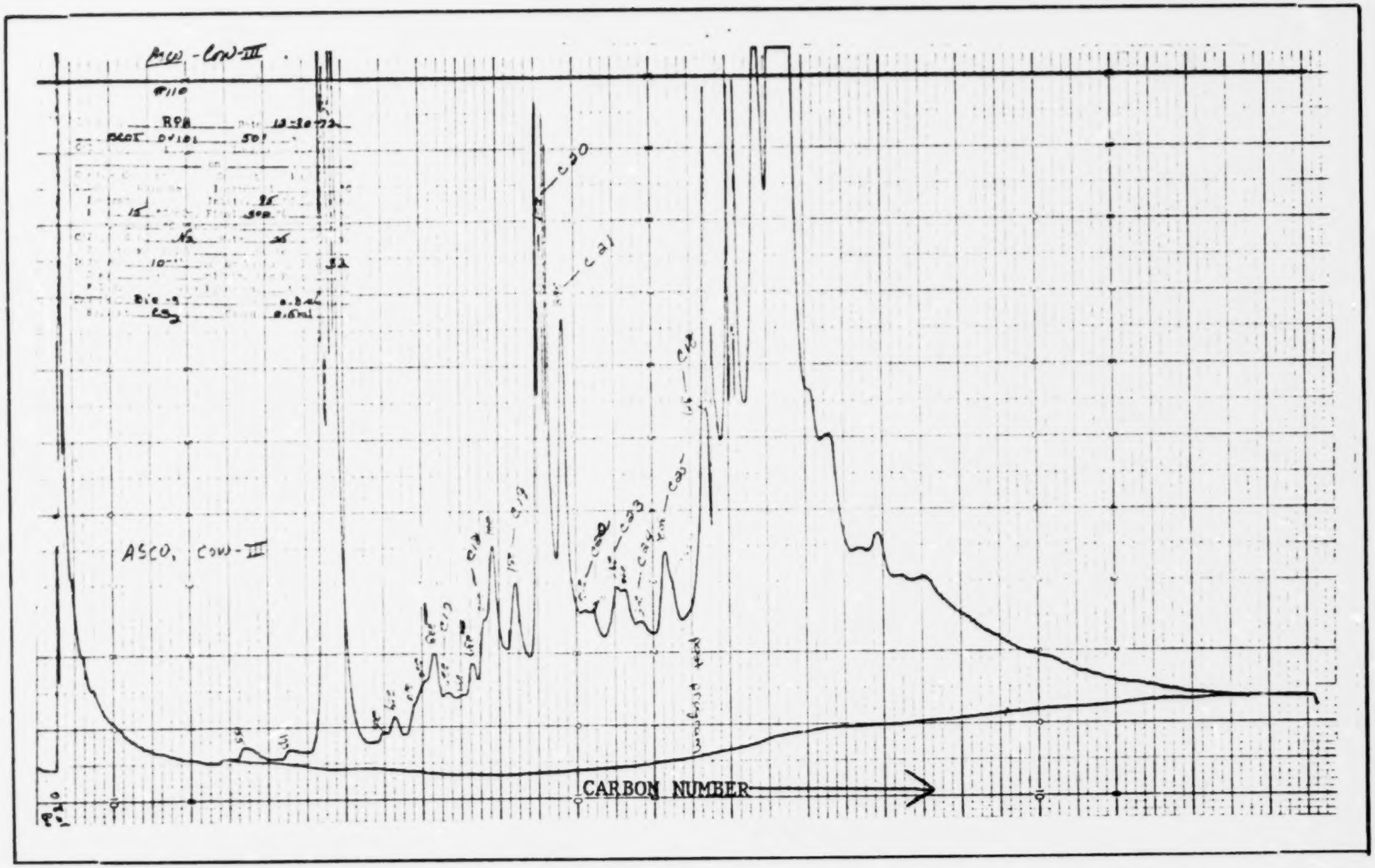


FIGURE 44

Chromatogram of Ascophyllum
Cow Island -- Survey III

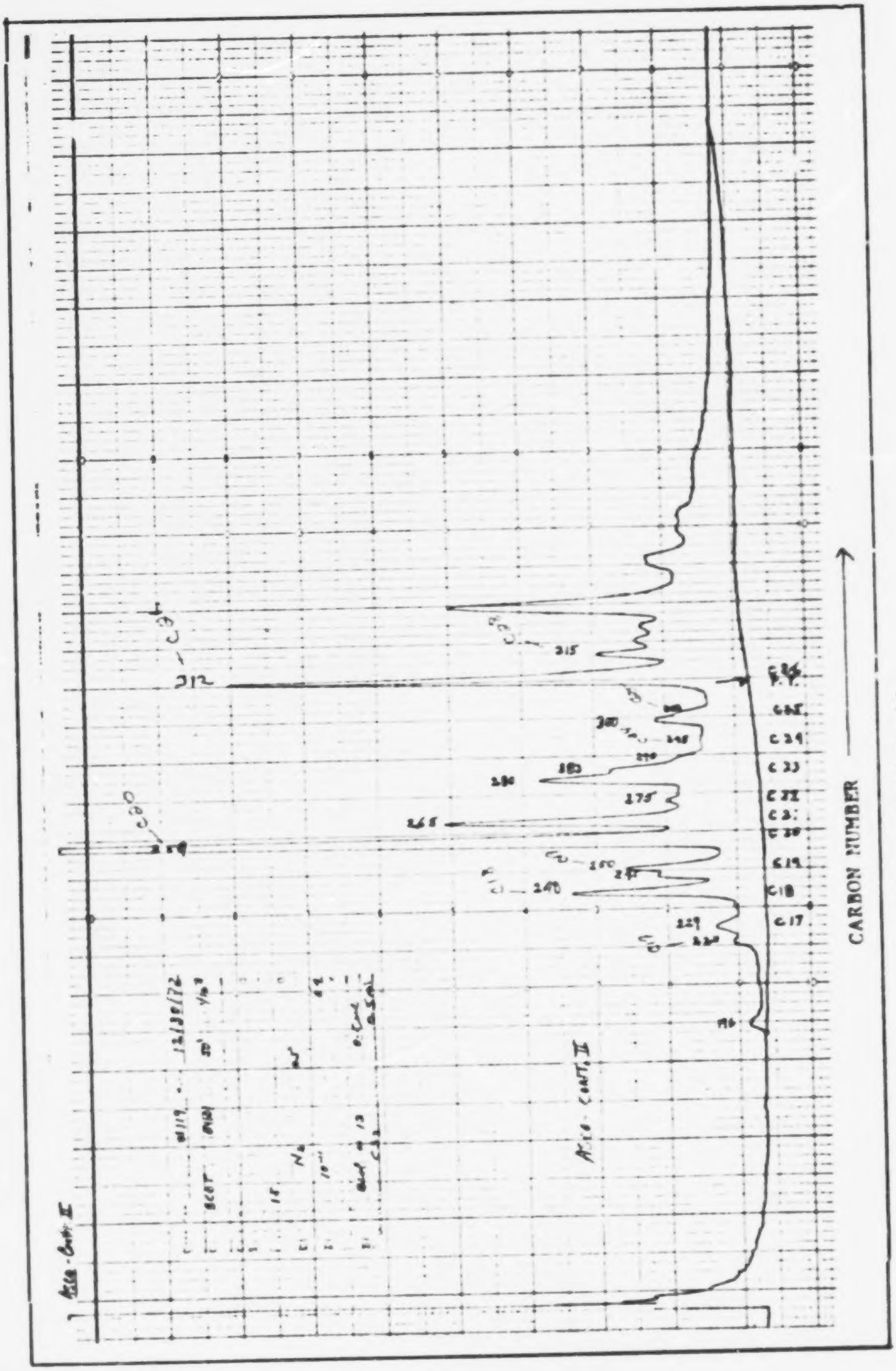


FIGURE 45

Chromatogram of Ascophyllum
Bailey Island -- Survey II

TABLE 5

TOTAL HYDROCARBONS IN WATER FROM THE MID-SOUND AREA

SURVEY	DEPTH	TOTAL HYDROCARBONS MG/L	RELATIVE ATTENUATION
I	Surface (1 ft)	0.4	32
I	Mid-Depth (30 ft)	1.4	32
III	Surface (1 ft)	0.6	32
III	Mid-Depth (30 ft)	0.7	32

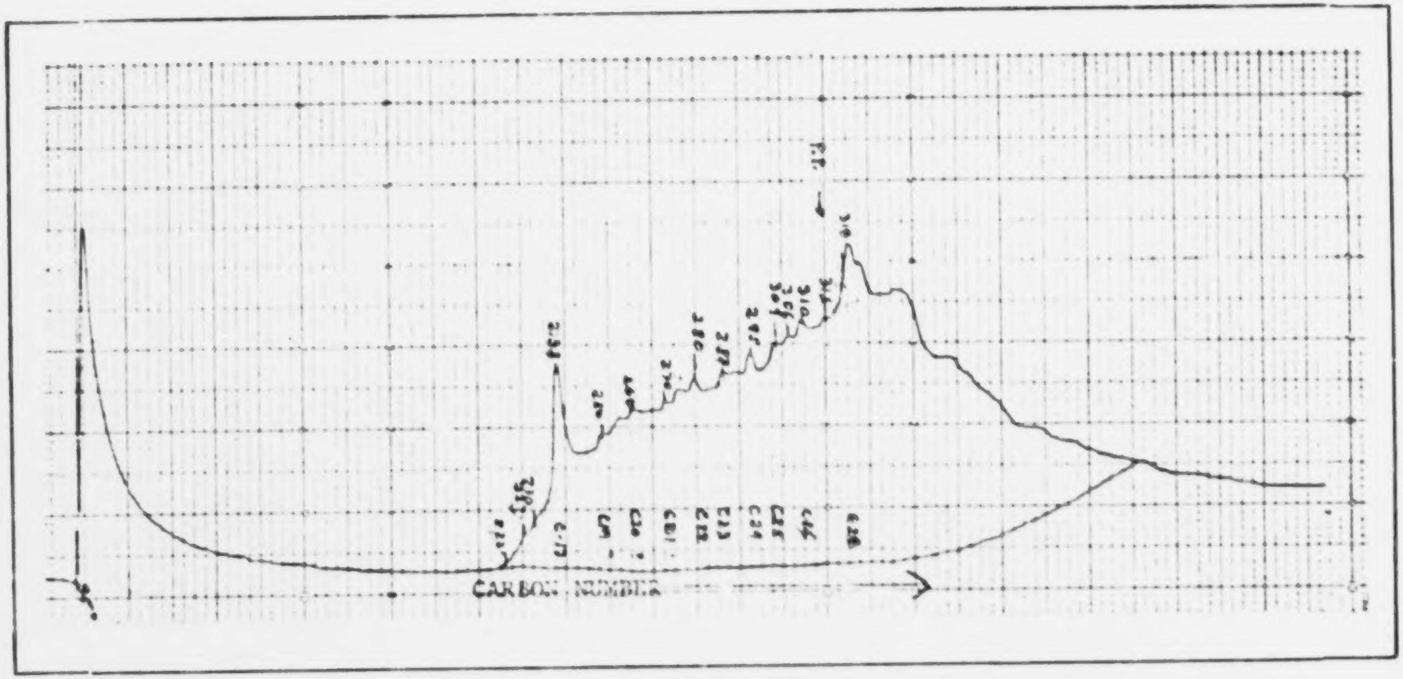


FIGURE 46

Chromatogram of Water
Mid-Bay Surface -- Survey I

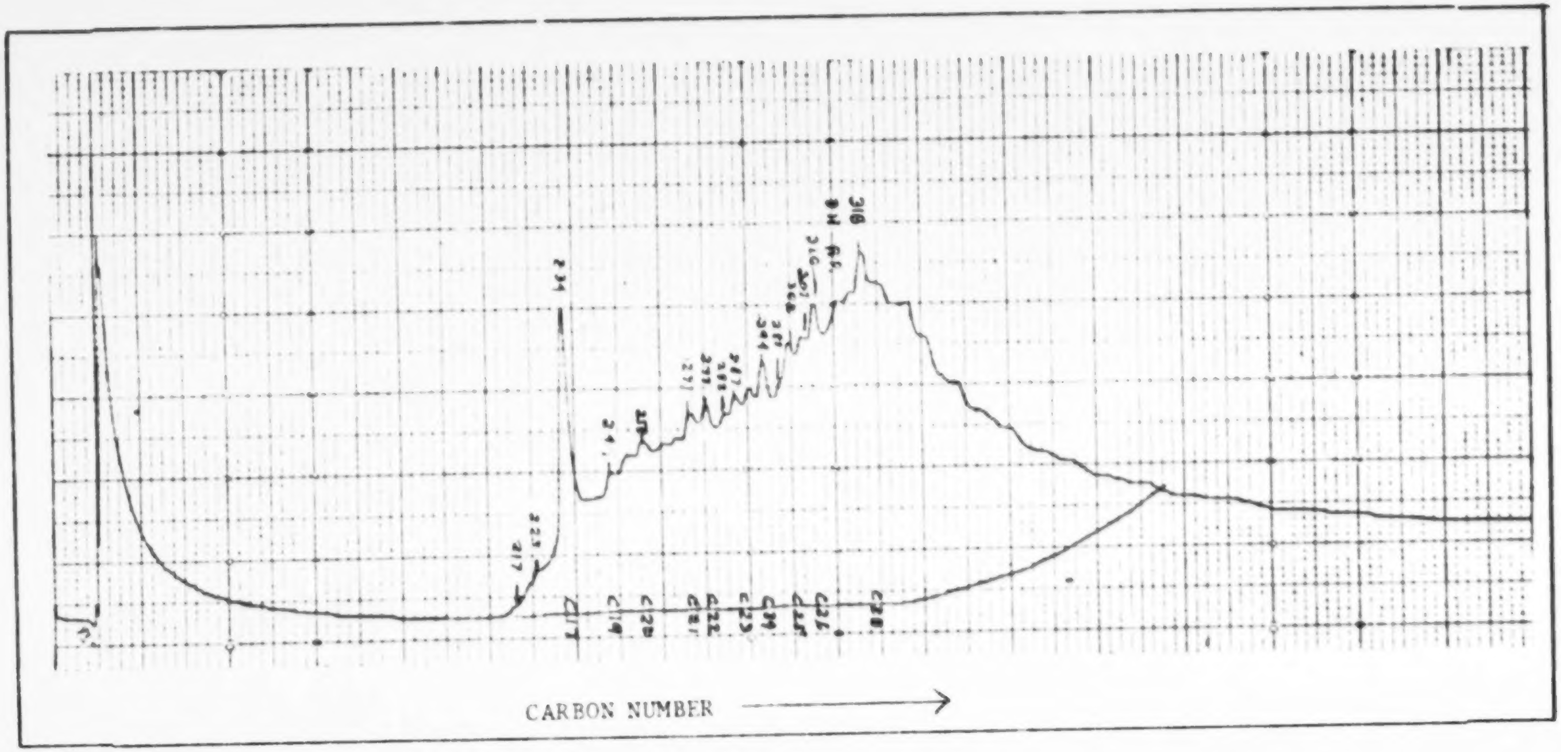


FIGURE 47

Chromatogram of Water
Mid-Bay 30 ft Depth -- Survey I

TABLE 6

QUANTITATIVE HYDROCARBON ANALYSIS

LONG ISLAND BEACH SAND

SAMPLE DEPTH	SURVEY	TOTAL HC MG/KG DRY WEIGHT
Surface - 10 cm	I	43,200
	II	29,000
	III*	432
20 - 30 cm	I	15
	II	380
	III*	137

*Survey made after beach removal operations surface. Therefore, the surface level in Survey III actually corresponded to the lower levels of Surveys I and II. The lower level of Survey III was lower than any level in the two previous surveys.

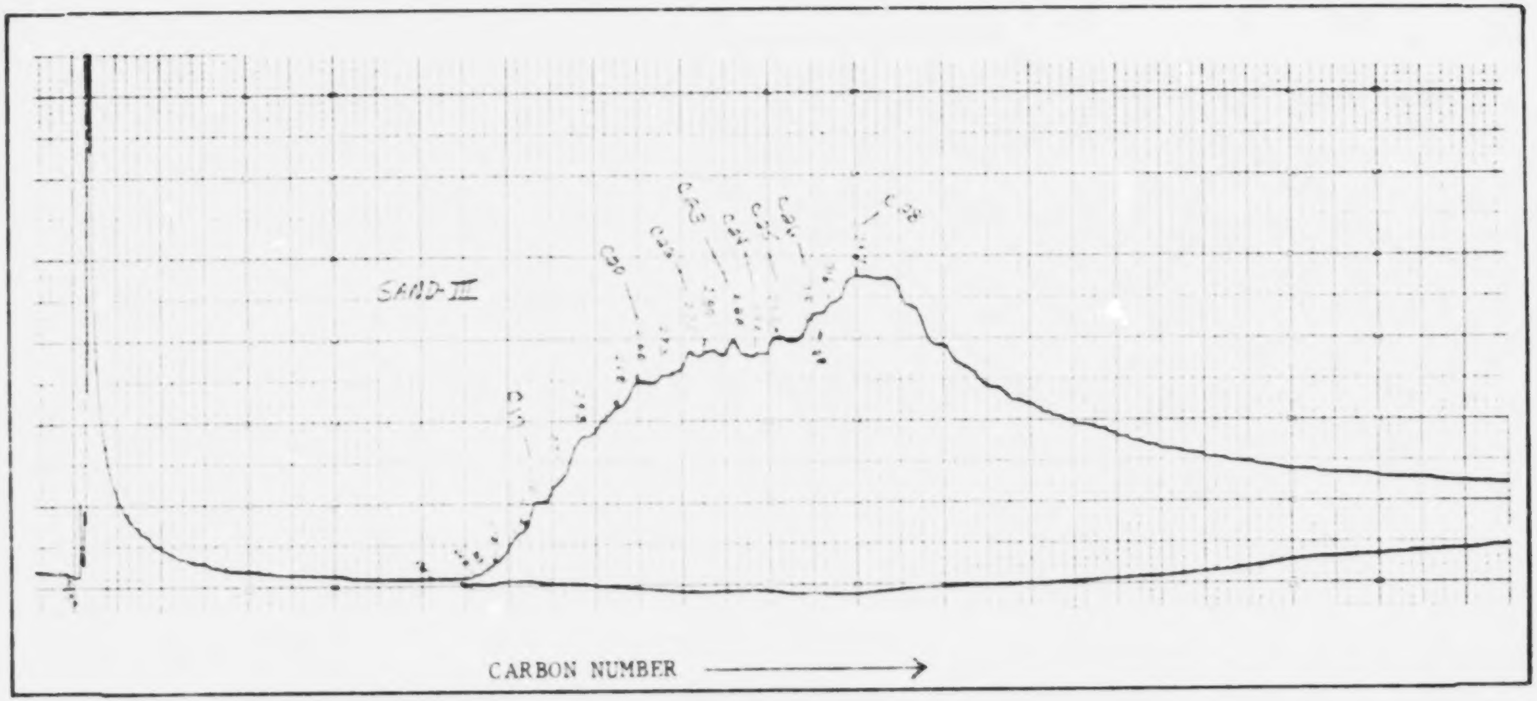


FIGURE 48

Chromatogram of Sand From West Beach
Surface -- Survey III

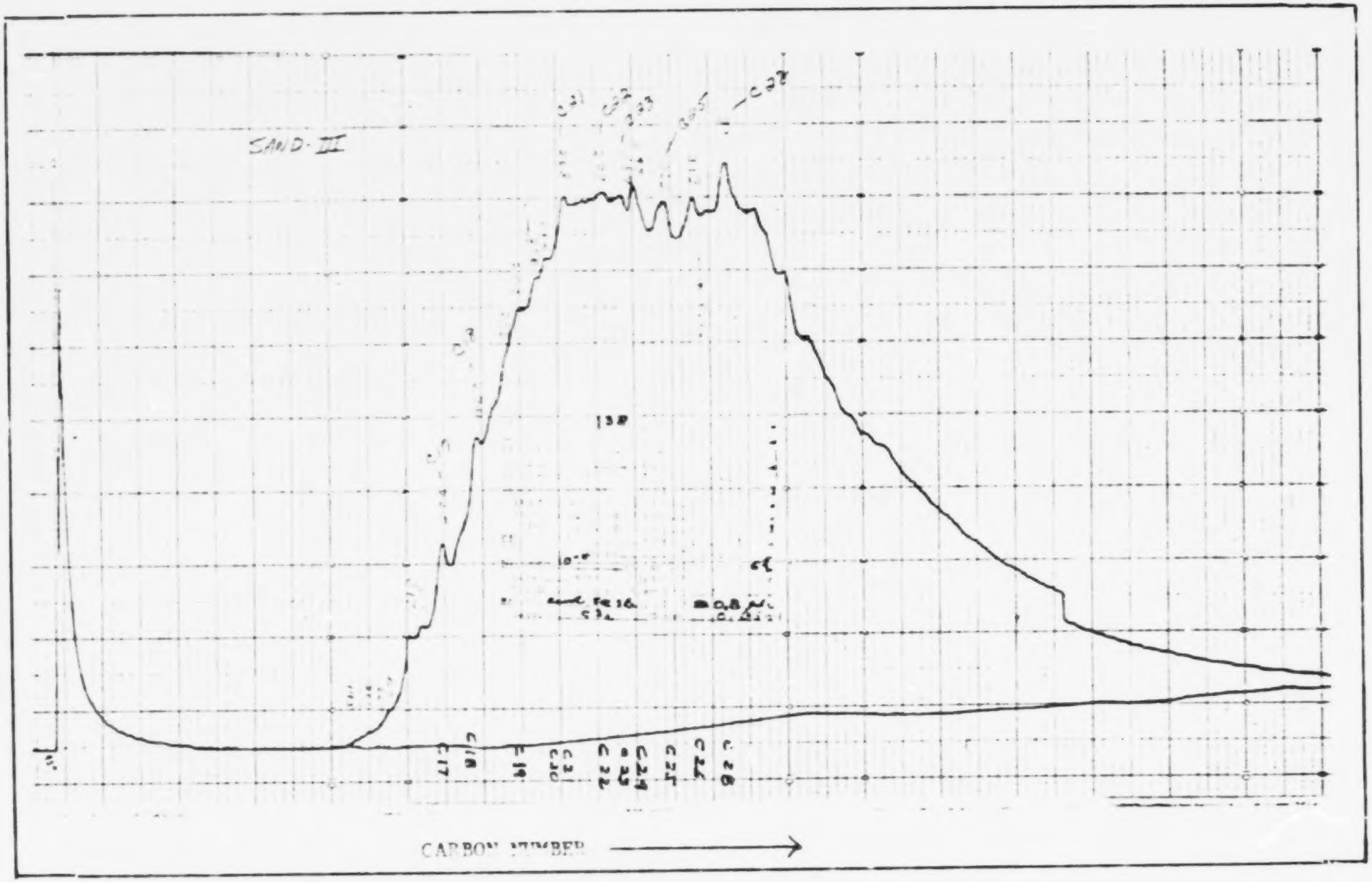


FIGURE 49

Chromatogram of Sand From West Beach
20 - 30 cm -- Survey III

SECTION VI

ECOLOGICAL RESULTS

Intertidal Mud Flats:

The stations at Cow Island (oiled) and at Beals Cove, Orrs Island (control) were intertidal softshell clam (*Mya arenaria*) areas (Figure 1). Salinities and water temperatures were comparable (Table 7). Sediment profiles were similar, the particles at Cow Island having a size distribution somewhat finer than those of Beals Cove during all but the final survey (Figures 48 AF). Neither the total abundance nor the species composition were very similar, however. Cow Island was primarily a polychaete - *Littorina* community, whereas Beals Cove was dominated by *Mya*, *Littorina* and *Gemma gemma*, with polychaetes conspicuously absent until the last survey (Table 8).

The species diversity remained essentially constant throughout the surveys at the control station, while at Cow Island it dropped drastically during Survey II with the loss of all infaunal species detectable by the methods employed. By Survey III, many of these started to return to the area. The length frequency analysis of the young clams for this survey (Figure 49) showed complete loss of the earlier sets seen in the Beals Cove profile, but apparent resettlement by new spawn (smallest size categories).

Total individuals at Cow Island (oiled) numbered nearly twice those of Beals Cove during Survey I, but they steadily declined over the three surveys, whereas the numbers at Beals Cove increased nearly six-fold. Notable losses at Cow Island occurred among bivalves and polychaetes, but the particular species lost did not correspond with the species present at the control station for comparison. Throughout the study, *Mya* were far more abundant at the control station than at Cow Island. All the adult *Mya* at Cow Island were located far up on the flat near the high water mark.

Subtidal Benthic Communities:

The experimental and control stations were located at the 20 ft depth (MLW) on Long Island and Bailey Island, respectively (Figure 1). Salinity and temperature regimes were similar (Table 7), but the sediment profiles for the Long Island station had a much greater proportion of fine silt than those

TABLE 7

FIELD TEMPERATURES AND SALINITIES

STATION	SAMPLING DEPTH	SURVEY I JULY		SURVEY II SEPTEMBER		SURVEY III NOVEMBER	
		TEMPERATURE °C	SALINITY 0/00	TEMPERATURE °C	SALINITY 0/00	TEMPERATURE °C	SALINITY 0/00
Cow Island	Surface	17.2	30.2	15.0	32.1	9.2	32.6
Long Island	Surface	14.4	32.0	16.0	31.0	9.0	32.5
Mid-Bay	Surface	16.1	31.8	15.3	31.2	---	---
Mid-Bay	Mid-Water	13.4	30.2	14.0	31.8	---	---
Beals Cove	Surface	20.3	29.8	15.0	31.2	9.8	30.0
Bailey Island	Surface	17.2	29.0	14.8	33.4	9.0	32.3

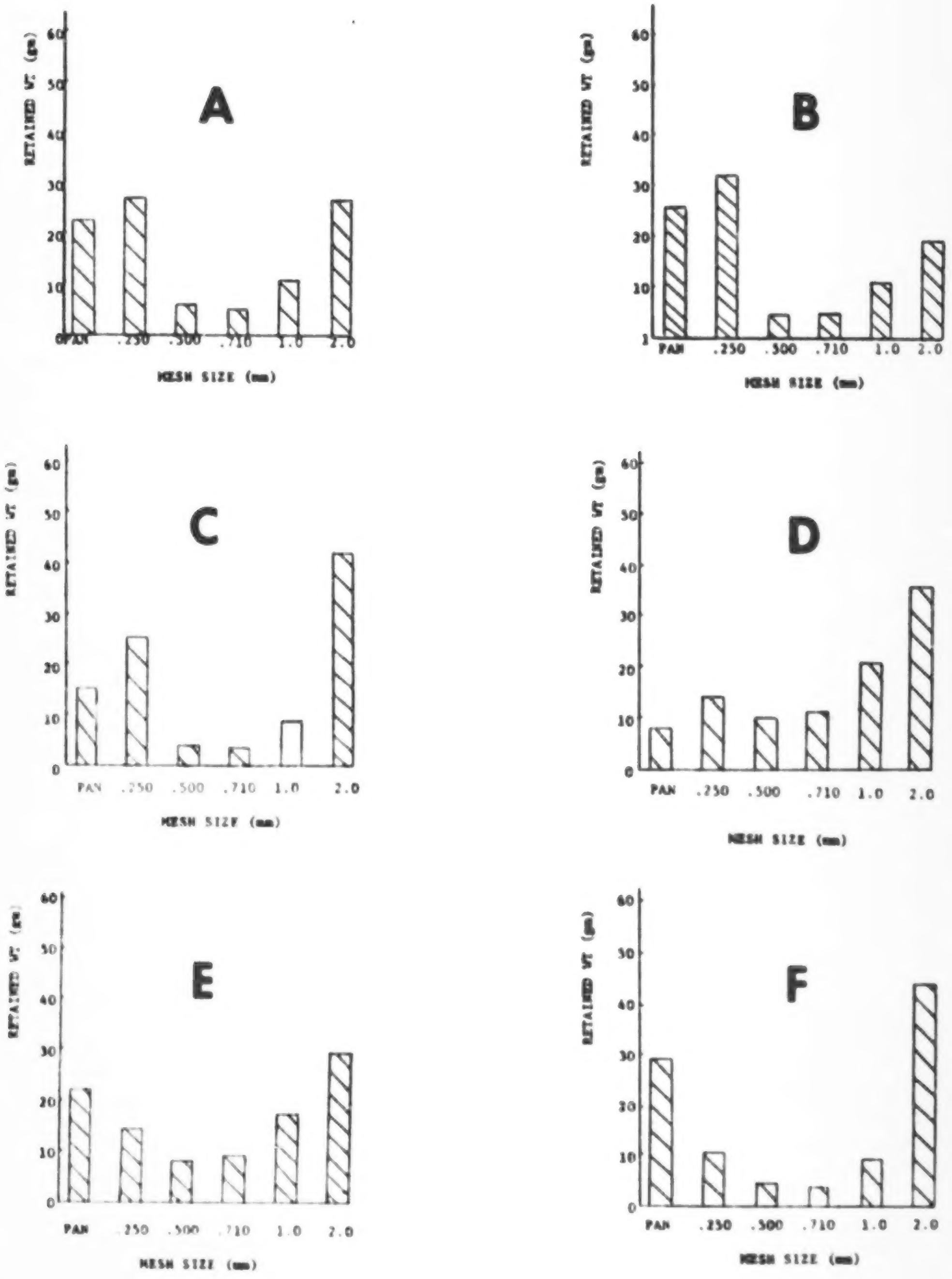


FIGURE 50

Benthic Sediment Profiles
(gm Retained per 100 gm of Sample)

TABLE 8

BENTHIC STATIONS

NUMBER OF ORGANISMS PER 0.09 M^2

SPECIES	COW ISLAND			BEALS COVE*			BAILEY ISLAND*			LONG ISLAND		
	SURVEY NO.			SURVEY NO.			SURVEY NO.			SURVEY NO.		
	I	II	III	I	II	III	I	II	III	I	II	III
Crustacea:												
Amphipoda	5	---	3	----	----	----	----	10	---	13	52	10
Isopoda	---	---	---	12	10	95	---	---	---	---	---	---
TOTAL	5	---	3	12	10	95	---	10	---	13	52	10
Echinodermata:												
Asterias forbesi	---	---	---	---	---	---	4	---	---	1	---	---
Echinarachnius parma	---	---	---	---	---	---	---	5	20	---	---	1
TOTAL	---	---	---	---	---	---	4	5	20	1	---	1
Mollusca:												
Acmaea testudinalis	---	---	---	---	---	---	4	---	---	---	---	---
Admenta conthayi	---	---	---	---	---	---	---	---	---	---	---	7
Cerastoderma pinnulatum	---	---	---	---	---	---	---	10	13	---	11	7
Cingula sp.	---	---	---	31	---	---	---	---	---	---	---	---
Crenella faba	---	---	---	---	---	---	4	---	---	---	---	---
Cumminga tellinoides	---	---	---	20	---	7	---	---	---	---	---	---
Cylichna gouldi	---	---	---	---	---	---	---	---	---	---	---	2
Gemma gemma	---	---	---	10	10	154	---	---	---	---	---	---

TABLE 8

SPECIES	COW ISLAND			BEALS COVE*			BAILEY ISLAND*			LONG ISLAND		
	SURVEY NO.			SURVEY NO.			SURVEY NO.			SURVEY NO.		
	I	II	III	I	II	III	I	II	III	I	II	III
Mollusca:												
Littorina littorea	130	70	47	1	10	7	12	---	---	---	---	---
Littorina obtusata	---	---	3	11	15	---	---	---	---	---	---	---
Littorina saxatilis	80	10	---	---	---	9	---	---	---	---	---	---
Macoma baltica	---	---	---	---	25	---	---	---	---	---	---	---
Macoma calcarea	---	---	---	---	5	---	---	---	---	---	---	---
Mercenaria mercenaria	---	---	---	---	---	---	---	---	---	2	---	---
Mya arenaria	5	---	40	51	205	236	4	---	7	1	6	10
Mya truncata	---	---	---	---	---	---	---	---	7	---	---	---
Mytilus edulis	10	---	---	8	---	26	---	---	---	---	---	---
Nassarius obsoletus	---	---	---	2	---	---	---	---	---	---	---	---
Nassarius trivittatus	---	---	---	---	---	---	4	15	7	---	---	---
Nucula proxima	5	---	7	---	5	---	4	10	---	229	83	111
Periploma leanus	5	---	---	---	---	---	---	---	---	---	---	---
Periploma papyratium	5	---	---	---	---	---	---	---	---	---	---	---
Pitar morrhuana	---	---	---	---	---	---	---	---	---	---	1	---
Retusa canaliculata	---	---	---	---	---	---	---	---	---	2	---	---
Rissoa sp.	---	---	---	---	---	171	---	---	---	1	---	---
Skenea planorbis	---	---	3	---	---	---	---	---	---	---	---	---
Yoldia limatula	---	---	---	---	---	---	---	---	---	---	---	1
TOTAL	240	80	100	134	275	610	32	35	34	235	101	138
Polychaeta:												
A. *Nephtys ingens*	---	---	---	---	---	---	---	10	---	---	25	---
B. *Pherusa affinis*	---	---	---	---	---	---	---	---	---	---	4	---

TABLE 8

SPECIES	COW ISLAND			BEALS COVE*			BAILEY ISLAND*			LONG ISLAND		
	SURVEY NO.			SURVEY NO.			SURVEY NO.			SURVEY NO.		
	I	II	III	I	II	III	I	II	III	I	II	III
Polychaeta:												
C. Polydora sp.	---	---	---	---	---	---	---	---	---	---	2	---
D. Chone infundibuliformis	---	---	---	---	---	---	---	---	---	---	11	---
E. Lumbrineris tenuis	---	---	---	---	---	---	---	10	---	---	20	---
F. Unidentified sp.	---	---	---	---	---	---	---	---	---	---	1	---
G. Phyllodoce anaitides	---	---	---	---	---	---	---	---	---	---	1	---
H. Unidentified sp.	---	---	---	---	---	---	---	---	---	---	3	---
I. Unidentified sp.	---	---	---	---	---	---	---	5	---	---	---	---
J. Terrebellid	---	---	---	---	---	---	---	---	---	---	4	---
K. Unidentified sp.	---	---	---	---	---	48	---	---	7	---	---	---
L. Unidentified sp.	---	---	---	---	---	---	---	---	---	---	---	---
M. Unidentified sp.	55	---	---	---	---	---	---	---	---	---	---	7
N. Nephtys sp.	---	---	---	---	---	---	---	5	---	8	---	---
O. Unidentified sp.	5	---	---	---	---	---	---	25	---	---	---	---
P. Unidentified sp.	---	---	---	---	---	---	---	5	---	---	---	---
Q. Unidentified sp.	---	---	---	---	---	---	---	15	---	---	---	---
R. Unidentified sp.	---	---	---	---	---	---	---	20	---	---	---	---
T. Nephtys incisa	---	---	---	---	---	---	---	---	---	---	1	---
U. Ammotrypane avlogaster	---	---	---	---	---	---	---	10	---	---	---	---
W. Unidentified sp.	---	---	---	---	---	---	---	---	---	1	---	---
X. Unidentified sp.	---	---	---	---	---	---	---	---	---	1	---	---
Y. Unidentified sp.	---	---	3	---	---	---	---	---	---	---	---	---
TOTAL	60	---	3	---	---	48	---	105	7	10	72	7

*Control Stations

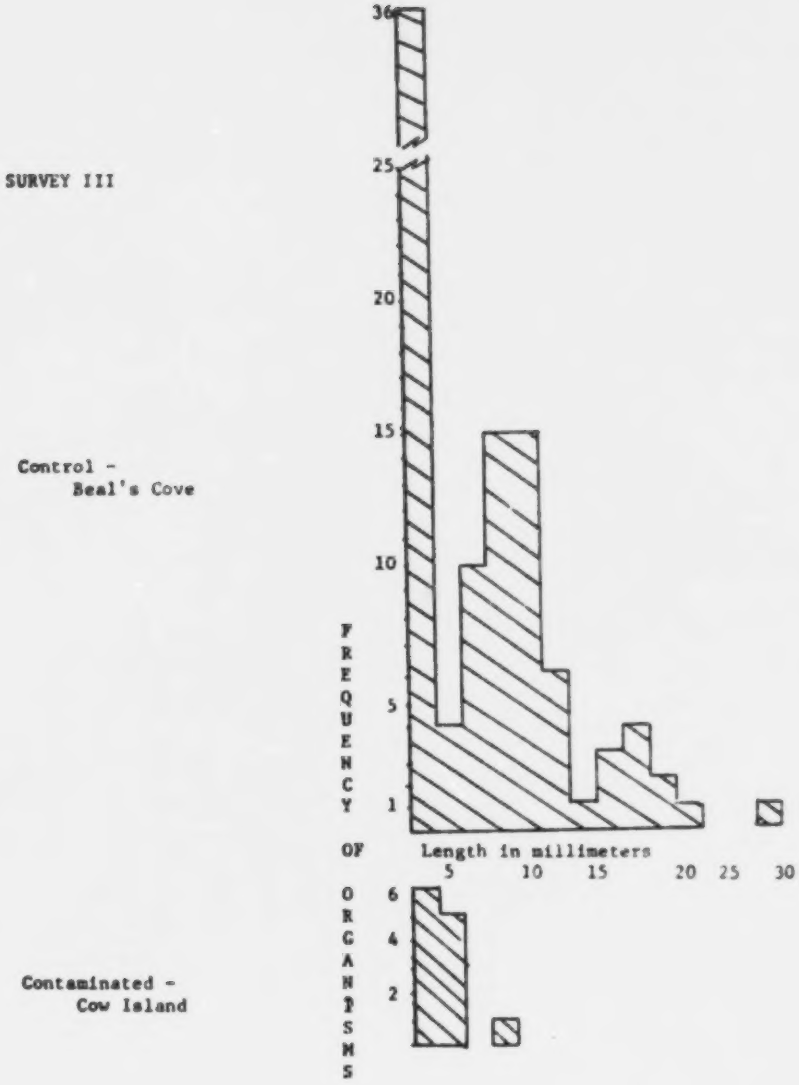


FIGURE 51

Size Frequency of *Mya*
for
Contaminated and Control Sites

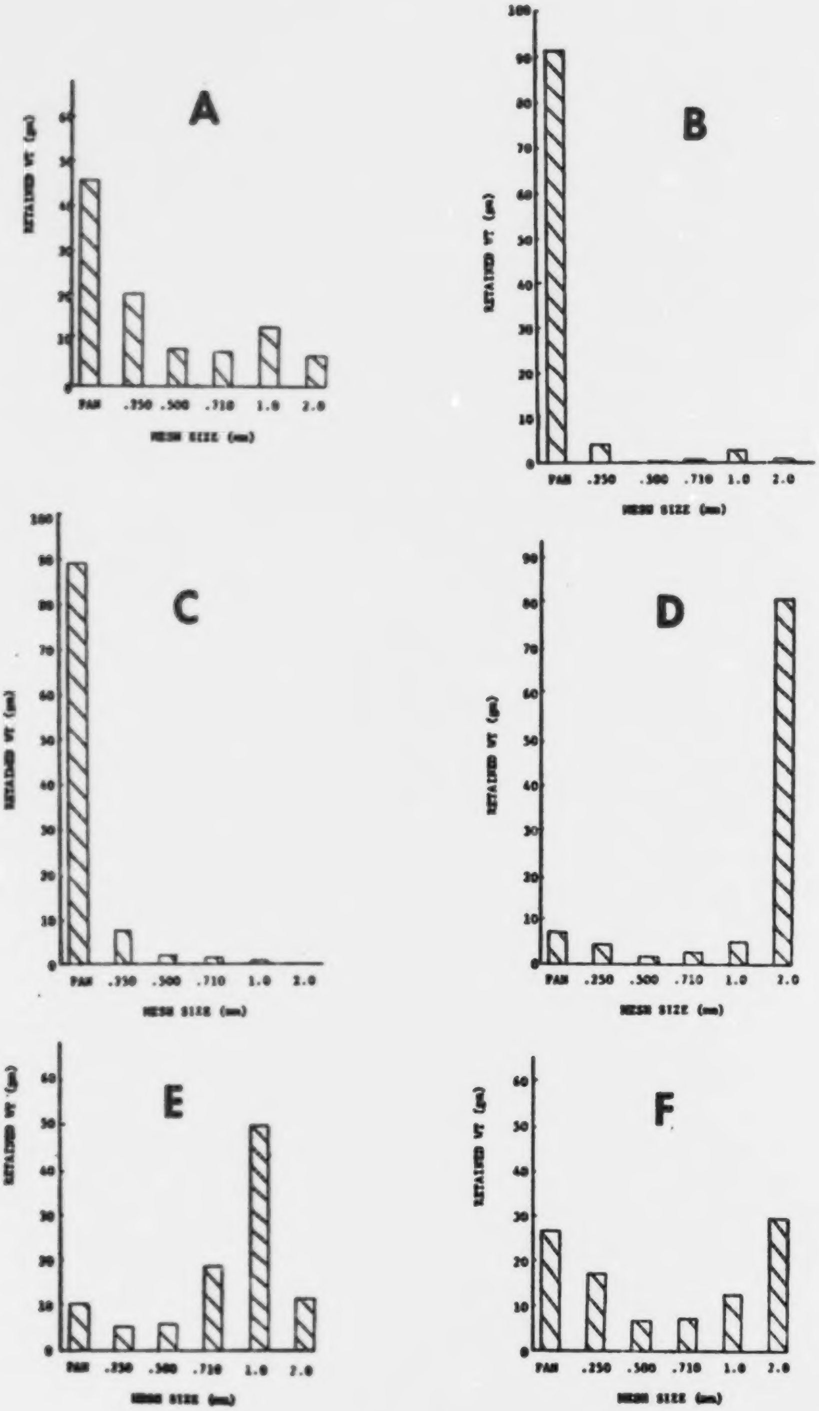


FIGURE 52

Benthic Sediment Profiles
(gm Retained per 100 gm of Sample)

of Bailey Island (Figure 50 A-F). On the first survey, the Bailey Island samples were collected inshore of a natural ridge where the substrate consisted of 90% black shale rock, 1% shell fragments and 9% miscellaneous sediment. Subsequently, the station was moved beyond the natural ridge to a more representative sediment type.

The total numbers of species were equivalent for both stations (Table 8), but the specific groupings at Long Island were different from those at the control, except for softshell clams (*Mya arenaria*), dwarf cockles (*Cerastoderma pinnulatum*) and nut clams (*Nucula proxima*). Of these, both *Mya* and *Cerastoderma* were present in comparable numbers at both stations, but *Nucula* was more abundant at the Long Island station where it was the dominant organism throughout the study in terms of abundance.

Polychaetes, abundant during Survey II, were scarce or absent on the first and third surveys at both stations. The polychaetes at Long Island did not correspond to those at Bailey Island, except for *Nephthys ingens* and *Lambrinereis tenuis*, present at both stations on Survey II.

Crustaceans, primarily amphipods, were more consistently present, as well as more abundant at the Long Island station. They were all of a single species.

Vertical Rocks:

The vertical rock stations at Long Island (oiled) and Bailey Island (control), shown in Figure 1, were highly comparable in their species composition. Rocks cleaned with hot water were not included in these surveys. Of the 24 different species found at both stations over three surveys, seven were found only at the control, a limpet (*Acmaea testudinalis*) and six species of amphipods. Of these seven, only the amphipods were sufficiently abundant at Bailey Island to constitute a significant difference from Long Island.

Amphipods were entirely absent from the Long Island station over all surveys, while they were both abundant and well diversified at Bailey Island (Table 9). Two amphipod castings were found at Long Island on Survey III, which suggests that there may have been an amphipod community before the oil spill.

Prominant species common to both areas included two algae, *Ascophyllum nodosum* and *Fucus spiralis*, and four invertebrates, the periwinkles (*Littorina obtusata* and *L. saxatilis*), rock barnacles (*Balanus balanoides*), and the spat of blue mussels (*Mytilus edulis*). The ranked order of

TABLE 9

INTERTIDAL ROCK STATIONS

NUMBER OF ORGANISMS PER 100 CM^2

	COW ISLAND			BAILEY ISLAND*			LONG ISLAND			BAILEY ISLAND*		
	SURVEY NO.			SURVEY NO. (Sloping)			SURVEY NO.			SURVEY NO. (Vertical)		
SPECIES	I	II	III	I	II	III	I	II	III	I	II	III
Crustacea:												
Amphipoda A	------	------	------	------	------	------	------	------	------	11	------	25
B	------	------	------	------	42	------	------	------	------	------	111	------
C	------	------	------	------	------	------	------	------	------	------	------	5
D	------	------	------	------	------	5	------	------	------	------	------	------
E	------	------	------	------	45	------	------	------	------	49	------	------
Unidentified sp.	------	------	------	------	23	------	------	------	------	------	------	------
TOTAL+	------	------	------	------	87	5	------	------	------	60	111	30
Balanus balanoides	836	981	777	1,130	1,049	743	1,036	1,425	1,014	1,730	1,631	1,400
Isopoda	------	------	------	------	8	------	------	------	------	13	------	------
TOTAL	836	981	777	1,130	1,057	743	1,036	1,425	1,014	1,743	1,631	1,400
Mollusca:												
Acmaea testidunalis	------	------	------	2	------	------	------	------	------	------	------	------
Littorina littorea	51	5	1	145	10	------	12	7	6	8	8	------
Littorina obtusata	175	548	405	733	2,629	995	210	137	215	1,059	418	564
Littorina saxatilis	.51	165	223	94	330	138	28	7	44	35	5	13
Mytilus edulis	3,337	1,458	912	1,844	3,069	879	58	25	140	678	498	563
Skenea planorbis	------	------	164	------	------	21	------	------	------	------	------	32
Thais lapillus	------	57	------	209	67	8	4	2	1	3	------	------
TOTAL	3,614	2,233	1,705	3,027	6,105	2,041	312	178	406	1,783	929	1,172

*Control Stations

+Total of identifiable amphipod types (does not include unidentified species) abundance among these invertebrates was the same for both stations, but the total numbers of individuals were consistently higher at the control station than at Long Island, except for L. saxatilis. Adult blue mussels at Long Island were scarce, indicating that while the rock served as a temporary substrate for the spat, Mytilus did not normally remain there to maturity. There was no apparent difference in abundance of species between the heavily oiled zones and those which lay below them. This indicated that smothering was not a primary effect of the oil at this station, unlike the area observed on the preliminary survey.

Sloping Rock Stations:

Intertidal stations on sloping rock areas at Cow Island (oiled) and Bailey Island (control) shown in Figure 1 presented much the same pattern as the vertical rock stations. Of the sixteen species found at both stations over all surveys, five species of amphipods and a limpet (Acmaea testudinalis), were found only at the control station. Of these, the amphipods were the most abundant and the most diverse (Table 9). The predominant species of algae and invertebrates common to both stations were the same as those found on the vertical rock stations, but the ranked order of abundance of the common invertebrates was not so consistent. Few adults of the blue mussel (Mytilus) were present, again indicating only temporary residence.

The periwinkle, L. obtusata, increased in abundance over the three surveys at the control station, gradually becoming the dominant species in terms of relative numbers. This increase did not occur at Cow Island where the abundance of L. obtusata was consistently lower than at the control. The other two common species, L. saxatilis and B. balanoides were more abundant at the control station than at Cow Island over Surveys I and II, but they dropped to relatively equal numbers by Survey III. Again, there were no differences in abundance between the heavily oiled zones and those below them.

Recolonization on the Rock Stations:

During Survey I, swaths were scraped clean of organisms on the sloping rocks at the Cow Island station (oiled), on the vertical rocks at the Long Island station (oiled) and at the respective control areas on Bailey Island. This was done to assess recolonization following the spill. The species present and their respective abundance were determined during the following surveys. Recolonization was based on recruitment and population ratios. These ratios are a method to establish the degree of recolonization and it is based on the following assumptions: (1) the control stations have remained oil-free, (2) the pool of organisms available for recolonization comes from areas adjacent to the cleared strips, (3) recolonization of the control areas reflect natural processes.

The recruitment ratio was formed by comparing the number of animals, regardless of species, on bared areas at the control station to the number on the bared areas at the oiled station (See Table 12). For example, during Survey II, 1201 animals were on the cleared swatch on Bailey Island (sloping rock control) and 197 animals on the cleared sloping rock strip at Cow Island (oiled). The recruitment ratio, R, is 1,201/197 = 6.1:1.

The population ratio is based on all species common to the control and oiled areas. It is formed by comparing the number of animals in the area adjacent to the control cleared strip to the numbers adjacent to the oiled cleared strip. Data for these ratios come from Table 9. For example, during Survey II on the sloping rock stations, there were 7,154 animals at the Bailey Island control station and 3,214 animals at the Cow Island oiled station. The population ratio, P, is 7,154/3,214 = 2.2:1 (Table 10). The population ratio is a "weighing factor" to account for differences in abundance between the two areas. Whenever the recruitment ratio exceeds the population ratio, more animals than would be expected by sheer differences in population sizes were moving on to the bared areas at the control station than on to a similar area at the oiled locations.

Observations on the Rookeries:

The rookeries at Ram Island (herring gulls and a few eider ducks) and Outer Green Island (eiders and cormorants) were visited on all three surveys. Inner Green Island (eiders, cormorants and gulls) was added on Surveys II and III. On the western shore of Ram Island, oil from the Tamano washed ashore and collected on rocks and in tide pools. On Outer Green Island, oily seaweed drifted onto the western shore. Oil slicks were prominent on the water surface in the area of all three islands during the first week after the spill.

The counts of dead birds on the islands are given in Table 11. Oil was seen on some of the carcasses, but the condition of the majority was too poor to tell whether they were oiled or not. On Ram Island, the birds appeared scattered about on the high bluffs as if pulled apart by a predator. In addition to the dead gulls, twelve live, oiled gulls were seen there on the first survey. One live, oiled gull was found on Ram Island. Gulls suffered the heaviest mortality with cormorants

TABLE 10

RECOLONIZATION OF SLOPING ROCK STATIONS (BY ZONES) AND VERTICAL ROCK STATIONS (WHOLE STATION)

SLOPING ROCK

		TOTAL NUMBERS OF INDIVIDUALS			
		SURVEY II (September)		SURVEY III (November)	
STATION	COMMUNITY ZONES	COW ISLAND (OILED)	BAILEY ISLAND (CONTROL)	COW ISLAND (OILED)	BAILEY ISLAND (CONTROL)
IV	Lichens	21	195	193	137
III	Periwinkles	20	201	93	230
II	Barnacles	54	341	229	337
I	Seaweeds	102	464	343	609
TOTALS		197	1,201	858	1,313
RECRUITMENT RATIO: (Control:Oiled)		6.1:1		1.5:1	
POPULATION RATIO: (Control:Oiled)		2.2:1		1.1:1	

TABLE 10

VERTICAL ROCK

STATION	COMMUNITY ZONES	TOTAL NUMBERS OF INDIVIDUALS			
		SURVEY II (September)		SURVEY III (November)	
		COW ISLAND (OILED)	BAILEY ISLAND (CONTROL)	COW ISLAND (OILED)	BAILEY ISLAND (CONTROL)
ALL ZONES		198	363	164	575
RECRUITMENT RATIO: (Control:Oiled)		1.8:1		3.5:1	
POPULATION RATIO: (Control:Oiled)		1.6:1		1.8:1	

TABLE 11

NUMBERS OF DEAD BIRDS COUNTED ON ROOKERY SURVEYS

STATION	SURVEY	GULLS	DUCKS	CORMORANTS
Ram Island	I	13	7	0
	II	150	1	0
	III	201	11	0
Outer Green Island	I	0	0	0
	II	9	2	2
	III	0	0	28
Inner Green Island	I	0	0	28
	III	22	5	29

second. Heaviest eider mortality was on the first survey when the slicks were on the water.

SECTION VII

DISCUSSION OF FIELD RESULTS

The thrust of the field study was to determine quantitatively in the presence of oil in the sediments, water and selected biota, in order that a determination of possible adverse effects of the oil on the organisms might be made. This study was also to assess the effectiveness of cleanup operations. Deleterious effects in this study are limited to death or removal of animals from the affected area. During the three-and-a-half months of the field investigation, no attempt could be made to determine long-term effects on reproduction or other sublethal damage.

Difficulties in Establishing an Adequate Control:

One of the greatest difficulties in oil pollution field studies has come to be the establishment of a control station which is close enough to present comparable environmental conditions for the ecological studies, but distant enough to remain free of the contaminant. Observations on the movement of oil on the surface during the first few days after the spill (Figure 1) indicated that Cousins Island and Great Chebeague, with their narrow and shallow passages, were deterring movement to the north along the coast, while oil moving offshore was being carried south, along the route of the non-tidal drift.

Despite visual sitings of the concentrations of oil, our chemical analyses indicated substantial movement north to the Bailey Island area within seven days of the spill and movement up into Harpswell Sound (Beals Cove) by early September. There was, however, continued movement of oil in Beals Cove causing the hydrocarbon pollutant to accumulate in the sediments over the three surveys, whereas levels of pollutant in the Hussey Sound area were declining by the third survey. In a previous study on Long Island Sound (VAST, Inc., Oil Spill, Long Island Sound, 1972), it was found that the final deposition of oil in the sediments did not coincide with visual sightings of the oil, while it remained on the surface. Blumer and Sass (1972) were forced to re-establish their control station twice during the first year of work on the West Falmouth spill because of the creep of polluted sediments into areas previously unaffected. In the present study, during both Surveys I and III, the oil was entrained in the water column in Hussey Sound at greater concentrations, 30 ft deep, than it was found in surface waters. In an area of such large tidal ranges (12 ft) it is likely that strong tidal currents washed the entrained oil and sediment northward.

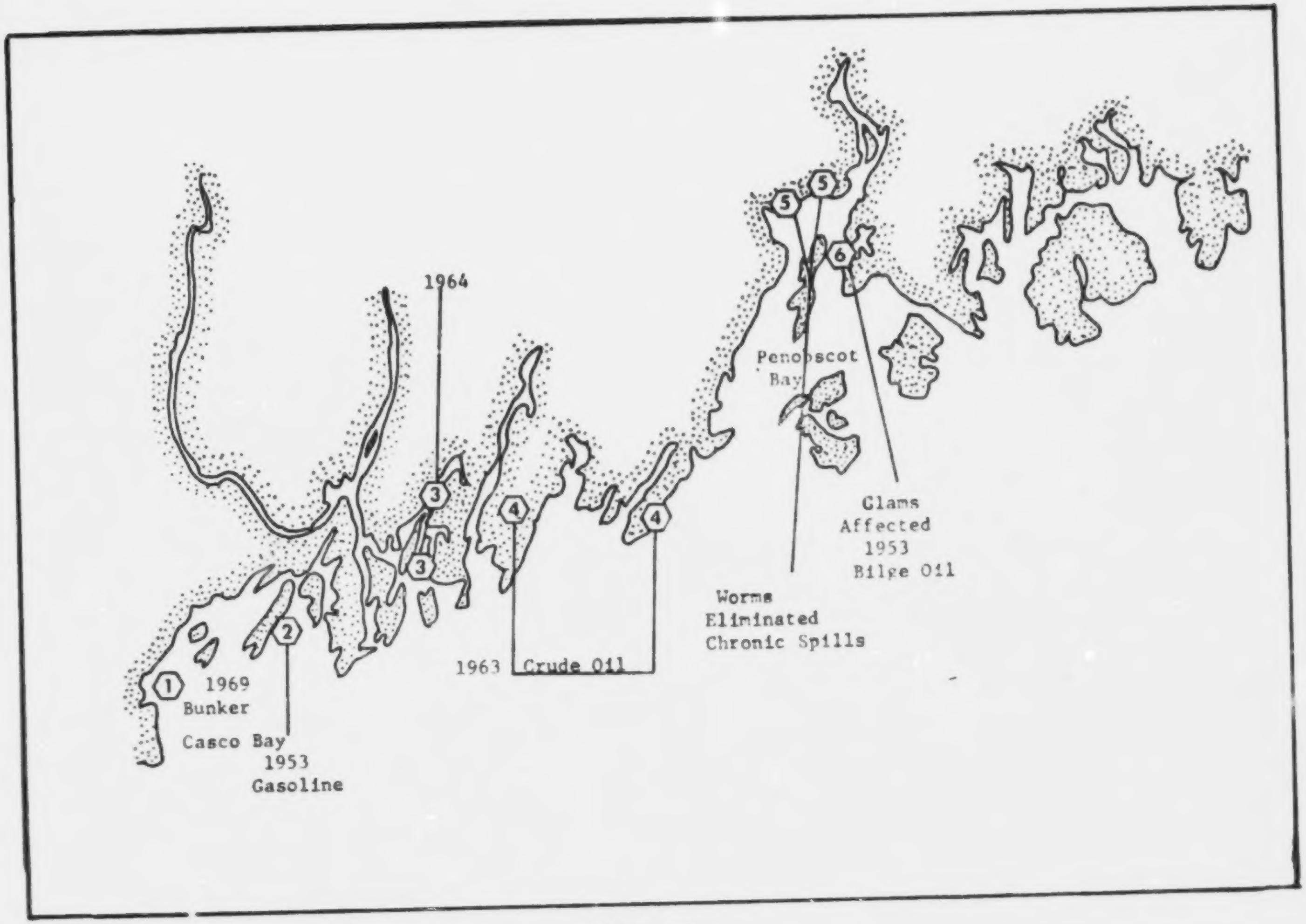

1964
3
3
4
4
1963 Crude Oil
Penobscot Bay
5
5
6
Clams Affected 1953 Bilge Oil
Worms Eliminated Chronic Spills
1
1969 Bunker
2
Casco Bay 1953 Gasoline

FIGURE 53

Oil Incidents on the Coast of Maine

TABLE 12

KEY TO FIGURE 51

RECENT OIL SPILLS WHICH HAVE BEEN REPORTED

BY

THE NATURAL RESOURCES COUNCIL OF MAINE

1. August 9, 1969. An estimated 2,100 to 8,400 gallons of Bunker-C oil was spilled from a tanker in Portland Harbor. Some of the oil washed ashore on Little Diamond Island.

2. December 1, 1953. An estimated 3,000 to 4,000 gallons of gasoline were discharged when a tanker ran aground between Orr's and Bailey Island.

3. April 24, 1964. Not less than 100 barrels were spilled by a ship at Birch Point, Wiscasset.

4. November 25, 1963. Twenty to twenty-five barrels of crude oil were spilled in Casco Bay. Weather conditions resulted in the oil being carried eastward to the vicinity of Penobscot Bay (H), where a southeast gale brought the oil ashore in the Friendship-Bristol-Bremen area. Five lobster storage areas, stocked at a full capacity of 750,000 pounds, were contaminated for varying periods of time.

5. Chronic oil spills at Searsport and Stockton Springs have eliminated the worm fishing in these areas. Dealers in the industry claim that oil contamination has reduced the survival time of worms, thus making them unsuitable for market. The bait worm industry has an annual value of over $1,500,000. and employs 1,200 people.

6. October, 1953. Oil from a boat at Castine contaminated a large area of clam flats. As a result of this spill, 81 fishermen were put out of work for six weeks and an estimated 3,690 bushels of clams were lost.

There are records of crude oil spilled in Portland Harbor in 1963 moving north-eastward as far as Friendship, Maine, well beyond the control area.

In the vicinity of Portland Harbor, especially the anchorages such as Hussey Sound, the continual spillage of small quantities of oil and the frequency of larger accidents is high and constitutes a chronic pollution problem to the sediments and associated biota of the area (Figure 51, Table 12). Just two weeks after the Tamano spill, the Aquario spilled 3 to 5 thousand gallons of No. 6 oil, plus some kerosene in the same general area. In 1971, 66 spills were recorded for Casco Bay alone and in 1972 the Tamano accident was the 41st reported incident (Adams, 1972). Oil falling on rocky intertidal areas, in contrast to oil entering the sediments, receives heavy washing and weathering. The biota generally have a shorter life span than the infauna, as well as protective mechanisms for avoiding short periods of stress (i.e., sealing their shells). Thus, they would not serve as long-term reservoirs for the oil. Once the oil is incorporated into the sediments, it will remain there for years with little further degradation (Blumer and Sass, 1972; Burns and Teal, 1971). It was, therefore, not surprising to find different faunal assemblages between Hussey Sound and the control area with regard to the mud flats and benthic stations, while the rocky intertidal assemblages were much more similar. Presumably, the infaunal community had already adjusted to the chronic level of stress by shifting to the more tolerant species. This implies that there is no satisfactory control area for studies of spills in chronically polluted areas, because presumably some shift has already taken place in the species composition between the two areas.

Accepting this handicap, it has been assumed for this study that since levels of contamination in the control area were low compared with those of the Hussey Sound area, and since the oil moved into the control area gradually as opposed to the massive coating of the shores of Hussey Sound, valid conclusions may still be drawn as to the ecological effects of the oil in both areas.

Accumulation of Oil in the Sediments:

The oil eventually collected in the sediments at all the muddy intertidal and benthic stations. For each area (Hussey Sound vs. Control), the intertidal muds accumulated a greater concentration of oil than the subtidal stations. Blumer and Sass (1972) reported the same relative concentrations for the West Falmouth area. Except for the third survey at Beals Cove, the concentrations of hydrocarbon in the sediments at the control area were far below those in Hussey Sound. At the Hussey Sound stations, the concentration of oil increased through the second survey which was before the beach at Long Island and the seaweed had been completely cleared. These may have acted as sources of further pollution along with the spill of the tanker Aquario. The control area was still accumulating oil in November, three-and-a-half months after the spill.

Accumulations of Oil in the Biota:

Chromatographic profiles and chemical results showed that in general, the Tamano type oil incorporated into the biota was much more chemically degraded than the residual oil in the sediments, but that in those species which retained oil, unresolved hydrocarbons, which are considered the most toxic fraction (Blumer, 1971), still remained. Blumer and Sass (1972) also found more intense biodegradation of No. 2 oil incorporated into the tissues of oysters and scallops than of that incorporated into sediments, but the toxic fractions remained high.

The different species of animals and plants accumulating the oil did not incorporate it to the same degree. Among the animals, the clams collected the highest concentrations. Their close association with the sediments has already been discussed in this regard. Blumer and Sass (1972) also found the oil highly concentrated in populations of the same species in West Falmouth. Scarrat and Zitko (1972) found that whereas No. 6 oil from the tanker Arrow was readily incorporated into the tissues of clams (Mya), scallops (Placopecten magellanicus) and the ribbed mussel (Modiolus modiolus), the periwinkle (Littorina littorea) apparently passed it through the intestine without absorption. The lobster (Homarus americanus) appeared least susceptible to the accumulation of oil in their tissues. Lobsters, after the Arrow spill, either did not accumulate the Bunker-C oil (No. 6) or successfully metabolized it (Scarrat and Zitko, 1972), whereas Blumer et al (1970) reported severe mortality to shallow water lobster populations from No. 2 fuel oil.

Of the two seaweed species tested, Fucus accumulated the oil to a much greater extent than Ascophyllum. This could have been due to a number of reasons: the location of the Fucus in the zone of heaviest contamination; the morphology of the Fucus strands, which are very flat and leafy, presenting a greater surface volume ratio than the rather rounded, digitated fronds of the Ascophyllum or the lipophyllic nature of the mucopolysaccharide substances on the fucoids which tend to absorb and hold the oil to a greater degree than the Ascophyllum.

Lethal Effects of the Oil:

The complete loss of benthic intertidal infaunal animals at the middle and lower tidal zones was witnessed by the second survey when the hydrocarbons in the sediment were highest. The population of soft clams at Cow Island was much more scarce than at Beals Cove during all surveys. The only adults there were found up near the high tide mark, which appears directly related to chronic spillage in the area continually killing off the young clams. Those which settle near the high water level would be out of reach during many of the spills. The Mya cannot completely close their shells and they readily incorporated the pollutant into their tissues. This presents a potential danger, not only to human consumers (Blumer, 1971), but also to shore birds feeding on the flats. Burns and Teal (1971) found high concentration of fuel oil hydrocarbon in herring gulls feeding in the vicinity of the West Falmouth spill well after the oil spill there. Apparently, when the concentration of hydrocarbon decreased to lower levels, as in Survey III, the young Mya were again able to settle. The ultimate survival and maturation of these young over the winter stress conditions cannot be known without further study.

The polychaetes sampled at Cow Island were in very poor condition as were those found during Survey III at the Beals Cove station, practically disintegrating on screening. This could have been an effect of the oil. Crapp et al (1971) reported that fishermen found worms exposed to crude oil to be flaccid and fragile.

It was significant that the rocky intertidal stations were comparable in specied composition, except for the amphipod populations. It is highly probable that either the Tamano spill or the chronic pollution of the area has caused the loss of the amphipods. These crustaceans have been found to be sensitive indicators of hydrocarbon contamination (Blumer et al, 1971; Sanders et al, 1972; Baker, 1971).

During the preliminary survey, we found significant washing away of fucoid algae and barnacles from the heavily oiled zones of rocky shoreline close to West Beach, Long Island. Also, the amount of algae floating in the water of the Hussey Sound area was evidence of the weakening of the holdfasts and loss of algae from the rocks. The stations chosen for continued monitoring were not in this area, because of the amount of cleanup inspection activity the area was receiving and because the extreme devastation did not lend itself to monitoring continuing effects. The stations which we monitored did not exhibit differential population densities between oiled and unoiled zones. They did, however, contain consistently smaller populations than the control stations. Since the faunal assemblages were comparable in the two areas, it must be assumed that the general environment of the Hussey Sound area is poorer (i.e., chronic pollution) or that the animals dropped away during the first few days after the Tamano spill and, therefore, were already reduced at the time of the first survey or a combination of both. There was some indication of the dropping away during Survey I when periwinkles were found lying upside down in tidal pools at Cow Island. In controlled experiments, the snails, Littorina littorea, L. obtusata, the whelk, Thais lapillus, and the limpet, Patella vulgata, suffered mortalities within six hours of being subjected to fresh crude oil, and even the weathered residue caused smothering, interference with movement and loss of ability to withstand wave action (Crapp, 1971). Narcosis has also been reported in snails exposed to oil.

The numbers of dead birds, particularly on Ram Island, were much higher than would normally be expected. The low count on the first survey may have resulted from the gulls and cormorants being on their nests with the young just hatching, rather than being out on the water amid the oil slicks. By comparison, the eider ducks, as water-based birds, suffered their mortalities as a group during Survey I.

Had the spill occurred in winter or during migration, effects on the thousands of waterfowl that collect in the Casco Bay area could have been far more serious. Even lightly oiled birds suffer from loss of their natural insulation in winter and die of exposure. Methods of rehabilitating oil-soaked birds can be expensive and relatively ineffective. Maine Audobon Society spent $800. to clean 23 birds oiled in the Tamano spill and ten of these survived. These survival rates and cleanup costs were better than many rehabilitation operations in other spills, but the investment per bird is still quite high.

Recruitment and Re-Population:

The results of the re-population studies on rock areas scraped clean for this study were inconclusive (see Table 10). The lichens which returned to cleared areas both on Hussey Sound stations and control stations are the first stages of successional growth on disturbed rock areas. The movement of Littorina into bared areas indicated the presence also of the microscopic bluegreen algae on which they graze. The movement of Thais, a carnivorous dog whelk, onto bared areas may merely have been from a random search for food. Furthermore, the recruitment ratios and the population ratios gave mixed results. These were calculated to determine whether the greater numbers of snails moving onto bared areas at the control stations were merely a function of the greater overall density of available animals in the control area. Thus, when the recruitment ratio was much higher than the population ratio, as at the sloping rock stations during Survey II, it meant that recruitment to the bared area was much greater at the control station even taking into account the fact that greater numbers of animals were available to be recruited. But by Survey III, the recruitment difference between oiled areas and control areas was about what would be expected from their relative population densities. By the same reasoning, recruitment to bared areas on vertical rock stations was lower at the control stations on Survey II than would be expected from the relative population densities and higher at the control station on Survey III.

As a further point, all animals repopulating the area were mobile adult members of the community, whereas the real test of substrate suitability will come with attempted settlement by the young of sessile populations, such as barnacles, blue mussels and seaweeds. The spawning peaks for these populations will not take place until spring and early summer, and thus, at least one year would be needed to assess the success of recruitment to these areas.

Effectiveness of Cleanup:

Cleanup was severely hampered by a lack of marine and pollution control equipment in the Portland area. Oil trapped beneath the vessel, oil surfacing outboard the booms and oil entrained in the water column at the 30 ft depth, as found in this study, were all situations which were not amenable to our current technology of treating oil on the surface. Oil entrainment in the water column has the potential to be a significant factor. Of special concern are such fractions as low boiling aromatics, cresols, xenols, napthols, quinolines, pyridines, and hydroxybenzoquinolines, because these components are highly toxic (Blumer, 1971) and also soluble in water.

A serious obstacle to cleanup of shore areas was finding a dumpsite for oiled debris. This problem resulted in piles of harvested seaweed and oil-soaked hay left above the tide lines on the shores. Stormy weather and rain then leached the oil back out of the debris and down over the shore or carried clumps of the wrack back out into the water for transport to new areas. The cropping of the seaweed itself appeared to be effective in removing oil from the intertidal area before it could leach back out into the water. The long-range effect of cropping extensive areas on the weed population per se can only be known if a survey is made of the success of resettlement on denuded areas over an annual cycle as compared with the condition and reproductive success of that which was left to purge itself naturally. Of the seaweeds which were not cut, only the Fucus, which was in the zone heavily covered by oil, continued to harbor substantial concentrations of the pollutant three-and-a-half months after the spill. Even so, considerable amounts of the oil had washed away and that which remained was severely weathered. Some of the seaweed strands beneath the oil were withered and necrotic and thus, the value of leaving the plant in the environment was questionable, especially since the oil purged from its surface by the waves would continue to contaminate elsewhere.

The cleanup of West Beach on Long Island by removing the layer of oil-soaked sand was shown by our chemical analyses to be effective in reducing oil in the surface layers by 98.5%. If this operation had been carried out within several weeks of the spill, it would have still reduced the oil by 99.96% in the surface layers and left much less residual concentrations for further leaching (1.45 mg rather than 43.23 mg per gram dry wt of sand). The experimental use of sorbent on the beach was definitely proved ineffective. The sand itself was a better sorbent than the materials mixed with it. The effect of harrowing the sorbent into the beach homogenized the oil and sand, leaving the beach highly unstable and causing severe leaching to subtidal areas. The operation to purge the rocks of oil with hot water under pressure was a slow and costly procedure with probably litle value, except aesthetics. The immediate effects severly disturbed the biota, but the long-term effectiveness will be determined by re-population in the spring.

SECTION VIII

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SECTION IX

ACKNOWLEDGMENT

We are most grateful to Carl Eidam, Environmental Protection Agency Oceanographer, Region I, for guidance throughout the study.

GLOSSARY

SCIENTIFIC NAME	COMMON NAME
ALGAE	
Ascophyllum nodosum	Knotted Wrack
Fucus spiralis	Spiral Rockweed
Fucus vesiculosus	Rockweed
ARTHROPODA	
Balanus balanoides	Rock Barnacle
Homarus americanus	American Lobster
ECHINODERMATA	
Asterias forbesi	Common Eastern Starfish
Echinarachnius parma	Atlantic Sand Dollar
MOLLUSCA	
Acmaea testudinalis	Atlantic Plate Limpet
Admente couthouyi	Common Northern Admete
Cerastoderma pinnulatum	Northern Dwarf Cockle
Crenella faba	Faba Crenella
Cuminga tellinoides	Tellin Like Cumingia
Gemma gemma	Nut Clam
Littorina obtusata	Northern Yellow Periwinkle
Littorina saxtilis	Northern Rough Periwinkle
Mercenaria mercenaria	Hard-Shell Clam
Mya arenaria	Soft-Shell Clam
Mytilus edulis	Common Blue Mussel
Nassarius obsoletus	Eastern Mud Nassa
Nassarius trivittatus	New England Nassa
Nucula proxima	Atlantic Nut Clam
Periploma leanum	Lea's Spoon Clam
Periploma papyratium	Paper Spoon Clam
Pitar morrhuana	Morrhua Venus
Retusa canaliculata	Channeled Barrel-Bubble
Yoldia limatula	File Yoldia

SECTION X

APPENDIX A

INSPECTION OF BEACH
ON SEPT. 6, 7 and 9, 1972

INSPECTION OF BEACH ON LONG ISLAND IN CASCO BAY

ON

SEPTEMBER 6, 7 and 9, 1972

On September 6, 1972, VAST, Inc., responded to a request by EPA to evaluate the present condition of the beach on the southern end of the NW shore of Long Island in Casco Bay and to advise (1) whether the beach should be cleaned up, (2) whether such cleanup should be undertaken immediately, and (3) whether the method of on-site cleaning proposed by Altenberg and Kirk provided a feasible alternative to the method of removal proposed by the Coast Guard, as advised by the EPA. We were further asked to comment upon the cleaning operations underway in the rocky area immediately north of the beach site.

CONCLUSIONS AND RECOMMENDATIONS

THE BEACH

1. The oil-soaked beach at Long Island presents a potential hazard through:

    a. The leaching of oil and oiled adsorbent to the water column for transport to new areas, including black duck, eider, cormorant, osprey and gull feeding grounds, intertidal mussel and clam beds.

    b. The erosion of oil-soaked sands to the benthic communities directly offshore and subsequent transport to new areas. Of special concern here are (1) contamination of lobsters with sublethal doses of substances potentially harmful to consumers, but undetectable by smell or taste, (2) entry and concentration of substances into the aquatic food web, and (3) degradation of the substrate as a settling area for new larvae and lethal to young stages.

2. This hazard is enhanced by:

    a. Seasonal effects. Erosional conditions typically set in with fall and winter stormy weather.

    b. Attempts at cleaning. The areas disturbed by cleaning are softer, their normal sorting pattern is upset and they are more vulnerable to erosion. Increased leaching from this disturbed area is already apparent.

3. We recommend that removal of the oil-soaked portion of the sand be carried out as soon as possible for the following reasons:

   a. The sooner the removal takes place, the smaller the amount of sand that will have to be removed, since (1) leaching deeper to new uncontaminated levels will continue to increase the depth to which the sand must be removed, and (2) the erosion of uncontaminated sand from above the tide line is adding material over the top which is additional yardage to be removed along with the old sand.

   b. The fall season has already begun and the weather conditions can be expected to deteriorate causing (1) increased erosion over the next six to eight months, and (2) deteriorating working conditions for the removal operations.

   c. The onset of winter will bring (1) flocking of shore birds to the inshore areas and their increased vulnerability to oil, because of low temperatures, and (2) additional temperature stress conditions to marine populations with increased vulnerability to the additional stress of oil pollution.

THE ROCKS

1. The lipophyllic nature of the mucopolysaccharide substances in the fucoid algae apparently enhances their absorption of oil, which is then leached back to the water column.

2. It is recommended that these algae be completely removed in heavily soaked areas and cut back in moderately contaminated areas, leaving the holdfasts for regrowth.

3. It is recommended that the harvested algae be completely removed from the area, rather than left in piles above the tide line where leaching will continue in rainy weather and storms will wash it back into the water.

4. It is recommended that the seawater cleaning operations on the rocks be discontinued, because (1) it is costly and not very effective in cleaning the rocks, (2) it is causing oil to be washed down over uncontaminated portions of the rocky shore community, and (3) it is highly probable that winter storms and ice scouring will effectively cleanse the rocks for re-population in the spring.

OBSERVATIONS

The beach site was visited on the afternoon of September 6, 1972, by Wadsworth Owen, Barbara Welsh and Virginia Lee of VAST, Inc., accompanying the EPA representatives. About a dozen persons were shoveling oil and sand into large drums from heavily paved surface areas. One of the workers stated that she had been involved with beach cleaning operations for about six weeks. Earlier in the week, adsorbent was raked into the sand to a depth of 4 to 6 inches over a patch area and raked out again after the tide covered the area, thus, floating the adsorbent to the surface where it was retrieved with shovels and deposited in oil drums. This worker observed that the beach appeared cleaner immediately after the operation, but by the next day, it was oily again, presumably from bleed from underlying sand and adjacent areas. She felt that hand raking did not penetrate deeply enough.

The surface of the beach consisted of large areas of pavement interspersed with areas of relatively clean sand. This constrasted with observations by the VAST field team immediately after the spill when the entire beach was paved to a depth 10 cm from the upper tide line to low water. Digging beneath the cleaner surface areas disclosed a distinct band of heavily oiled sand from 2 to 4 inches wide and lying from 2 to 4 inches beneath the cleaner surface area. The band edges were sharply defined and clear sand was encountered below it. In areas where a pavement existed at the surface, we observed a band of clean sand beneath the pavement, then a fairly distinct band of oiled sand before encountering the clean sand again at depth. It appears that the clean sand has eroded from uncontaminated sand or leaching of oil from adjacent areas to repave the surface. We estimate that the depth of contamination of the beach varies from 2 to 8 inches. In the area where raking had been attempted, the sand was homogenized from the surface to approximately 6 inches, consisting of oil, sand and the perlite adsorbent.

We inspected an uncontaminated beach of about the same grain size and NW exposure on Peaks Island. There we found clumps of living mussels, starfish, aggregations of gammarid amphipods beneath larger rocks, many Nereis virens and a red worm probably the oligochaete Clytella. There was a large amount of clean Fucus wrack along the tide line colonized by amphipods. Some caution must be exercised in comparing this beach with that on Long Island. This beach is probably normally a more stable beach than that of Long Island, resulting from its position out of the main currents of Hussey Sound. Thus, under normal conditions, there is most likely a sparser fauna at Long Island.

On September 7, 1972, five members of the VAST field team visited the beach on Long Island with representatives of the EPA to observe further experimentation with the cleanup method of Altenberg and Kirk. Three types of adsorbent were harrowed into a stretch of beach about 40 ft by 200 ft at about mid-tide level. When the tide rose to cover the stretch, it was harrowed again with 12-inch discs and a team of horses just below the tide line. During this phase of the operation, a boom was deployed out-board of the area to retain the oil-soaked adsorbent and any oil which came to the surface. The used adsorbent was then shoveled into barrels. Seawater from a pressure hose was used along the tidal edge to prevent resettlement of the oil.

During the retrieval portion of the operation, two divers ran transects of underwater observations from outside the boom into water about 25 ft deep. They observed that the beach sloped off fairly regularly with low ripple zones 1 to 2 inches high. It was coarse sand and cobble until it reached a drop-off of about 1 ft. The drop was about 150 ft from the upper edge of the beach area and about 50 ft offshore during the harrowing, but only 5 ft below the tide line, as measured later in the day. The area inshore of the drop was completely oil-coated. Small dark flecks or blobs of oil were visible all over the surface. Beyond the drop was an area of larger rocks interspersed with fine sand, so that the basic substrate was considerably finer grained than the area before the drop. Little algae were growing in this swatch, which extended about 20 ft beyond the drop-off to a zone of eel-grass. Beyond the eel-grass zone was Laminaria. The zones outside the drop-off appeared free of oil.

There was much silt in the water column, especially just outside the boom operation. A southward moving current appeared to be keeping the material in suspension. At one point, pieces of foam adsorbent between 0.75 and 1.5 inches in diameter were seen in the water column at various depths, carried out under and beyond the boom.

In the fine sand beyond the drop-off, many very small (less than 1 mm) Littorina peppered the bottom, perhaps as many as 100 in a four-inch square. There were many crabs (Cancer irroratus), estimated at a density of about one per meter squared; also two species of starfish, sea scallops (Placopecten magellanicus) and hermit crabs (Pagarus). The starfish were estimated at about the same density as the crabs, with scallops and hermit crabs perhaps only one-third as dense. There were many horse mussel shells seen, but no live mussels. Five young flounder were observed between the grass beds and the drop and one was seen over the oiled area. There were many snails of the genus *Thais* around the kelp and on the rocks. Aufwuchs on the *Zostera* comprised worm tubes and *Littorina*. *Littorina* were also on the kelp. Burrowing worms were evident from their tubes and castings in areas between the rocks. During this dive, a sample of the sediment was taken of oily sand above the drop-off, another sample beyond it and a water sample was taken just beyond the boom.

Wading observations beyond the boomed area during the cleanup phase showed the water surface peppered with small, dark blobs of oil and some adsorbent. When the substrate was disturbed, oil blobs and adsorbent bubbled to the surface from the harrowed portion. When an area which had not been harrowed was disturbed, some oil did bubble to the surface, but in very much smaller amounts.

The beach was again observed over the harrowed portion on the next low tide. The oil was more apparent at the surface of the experimental plot than it was in undisturbed areas. Again the process had resulted in homogenization of sand, oil and adsorbent to a depth of 20 cm and the bearing strength had decreased to a point where it was difficult to walk over. Samples of sand at depths of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm were taken for hydrocarbon analysis from within the harrowed area and in an undisturbed area. Samples of the homogenized portion were collected for analysis of the amount of adsorbent remaining in the sand. The natural sorting of the beach was completely disturbed with apparent loss of fine sand at the surface.

There were areas of perlite adsorbent scattered over approximately the upper third of the intertidal zone and also areas of green foam. The adsorbents used were silicone treated perlite made by Whitmore Products, Inc., of Roslindale, Massachusetts, and Insulfoam, Urethane masonary fill insulation made by Foam Products Plastics Corp., in Haverhill, Massachusetts. The perlite still appeared white after use. The foam, when mixed with the sand, appeared to adsorb little oil. When seen floating on the water inside the boom, some of the pieces did pick up a large amount of oil.

Our conclusions were that the method released oil from the sediments, but the bulk of the oil remained in the sand. It would appear that the sand is differentially more adsorbent than the foam and that little direct exchange took place. The bulk of oil adsorbed within the boomed area was probably taken up after its release to the water.

The disturbance of the sand resulted in a much less stable substrate, which is very likely to increase the rate of migration of contaminant to the clean areas beyond the drop-off. The worked area appears to be much more vulnerable to leaching from rain, as well as tidal action increasing the danger. The homogenization of the upper layer has increased the depth of sand which must be removed to cleanse the beach. It has also entrapped adsorbent particles which will continue to pop out and float away with subsequent tidal cycles, spreading contamination. Any natural stability which might have been achieved to isolate the oil, such as sun-baking at the surface and covering with clean sand was destroyed by the harrowing, so that erosion and increased bleeding to the water column seems inevitable. In the water off the harrowed portion, there was a distinguishable area of greater leaching observed on September 9, 1972, two days after the trial.

ROCKY SHORE ZONE

The rocky shore zone on Long Island was being cleaned by pressurized seawater at 170°F. The saturated Fucus had been removed from the rocks before the pressurized water was applied. The method appeared to take a large amount of oil off in the immediate vicinity of the workers. Other areas, declared already finished, did not appear improved to any great extent. Some cleaning was carried out when the tidal level was below the contaminated zone, causing the oil to pass over this zone, which indicated poor supervision of the project.

The area outside the cleaning operation was inspected by one of our divers. There were lots of bottles and small rocks over a silt bottom with some gravel. There were eel-grass (Zostera) and kelp (Laminaria) beds offshore which were not as dense as those off the beach. This could have resulted from the greater boating traffic in the area, which is just south of the public landing. The area was inspected to the 25 ft depth. There was no shelf formation. There was much suspended matter in the water, but no visible oil on the bottom. The suspended material was small, white flaky particles, much like the floc observed below the oil in the F. L. Hayes spill in Long Island Sound near the Connecticut shore.

The fauna were generally more diverse and more abundant than that observed off the beach. Hermit crabs (Pagarus) and starfish were most abundant at an estimated density of three per square meter. The crab Cancer and the sea scallops were estimated at one per meter squared. Empty urchin casts were found, but no live urchins were seen. Leather worms were apparent from their burrows and mucus traps at an estimated density of one worm every three meters squared. Littorina and Thais were also present.

It was the opinion of our divers that this section was not being contaminated by the rock cleaning operation. We feel that the rock cleaning is not very effective relative to its expense. It appears that stripping the rocks of the heavily contaminated seaweeds does help prevent heavy leaching. We do not know whether stripping accelerates the return to a normal condition. We are attempting to determine this at our rocky shore station under our task force contract to EPA.

APPENDIX B

EVALUATION OF CLEANUP OPERATIONS
and
ANALYSIS OF THE LONGER-TERM BIOLOGICAL EFFECTS

ABSTRACT

This report presents the results of a ten-day survey of both the intertidal rocky zones and beaches in Casco Bay conducted by TRC - THE RESEARCH CORPORATION Of New England in August of 1973. The purpose of the survey was to assess the effectiveness of beach and rock cleanup operations and the longer-term biological effects one year after the TAMANO oil spill, which occurred in July of 1972.

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CONCLUSIONS

With respect to the four major objectives of the study reported herein, the following conclusions can be supported:

(1) One year and one reproductive cycle after the TAMANO oil spill, young of the dominant intertidal species have recolonized the uncleaned rocks of Casco Bay. However, the total species diversity and abundance [illegible]iled stations are still lower than at the control stations.

(2) Cleaning of oiled rocks of the lower tidal zone by means of pressurized hot water appears to aid the survival of organisms.

(3) Seaweed cropping to prevent re-introduction of oil into the water column has a deleterious effect on its re-growth as opposed to natural recovery of the seaweed.

(4) Beach Cleaning -- The beach removal procedures used at Casco Bay after the TAMANO spill did remove a large portion of the oil, and it did not adversely alter the physical characteristics of the beach at Long Island.

(5) Although some clams survived one year following oil contamination, the clam flats on Cow Island are still disturbed.

(6) Reduction of diversity of amphipods at the control station during this survey, with a simultaneous re-occurrence of some amphipods at the oiled stations, may reflect some oil encroachment into the control areas.

(7) The absence of amphipods at the oiled stations in the first three surveys and then a reduction at the control areas during this survey suggest that these animals are highly sensitive indicators of oil pollution.

RECOMMENDATIONS

(1) Ranges of temperature and pressure should be determined to increase the effectiveness of rock washing in the upper tidal zone.

(2) Beach removal procedures used at Casco Bay were effective and should continue to be used in similar situations.

(3) The feasibility of establishing indicator organisms should be investigated. Basic knowledge of their behavior, physiology and ecology will improve biological assessment of an oil spill.

(4) Rigorous extraction methods, such as Soxhlet extraction, should be incorporated into the analytical procedures when sediments are analyzed for oil content.

(5) Cropping seaweed to prevent re-introduction of oil into the water column should be initiated only after careful consideration of the environmental priorities.

INTRODUCTION

In July 1972, the tanker TAMANO struck Soldiers Ledge in Casco Bay, Maine, tearing a hole in one of her tanks and spilling a reported 100,000 gallons of Number 6 Fuel Oil of the low pour variety. Short-term biological effects of the spilled oil were studied by VAST, Inc., under contract to the Environmental Protection Agency (EPA), during three field surveys in July, September, and November of 1972.

The EPA decided to determine the effectiveness of beach and rock cleaning operations. An additional objective was to investigate longer-term biological effects of the oil spill in Casco Bay. Accordingly, TRC -- THE RESEARCH CORPORATION Of New England, a subsidiary of VAST, Inc., was commissioned by the EPA to conduct an additional survey during August, 1973, for these purposes.

This report presents the results of a ten-day survey conducted at some of the same stations in Casco Bay used in the three earlier surveys. The same sampling and analytical methods used in the previous surveys were used again to provide comparative data.

The specific objectives of the study were:

1. To determine the recovery and general health of the intertidal population affected by the TAMANO spill after one year and one reproductive cycle, i.e., the longer-term impact.
2. To determine the effectiveness of the rock cleaning operations conducted immediately following the spill.
3. To determine the long-term effectiveness of beach cleanup procedures employed just after the spill.
4. To determine if the absence of clams and amphipods noted previously at the stations impacted by the spilled oil can be attributed to the TAMANO spill.

METHODS

The following experimental design was used in this re-survey to attain the program objectives:

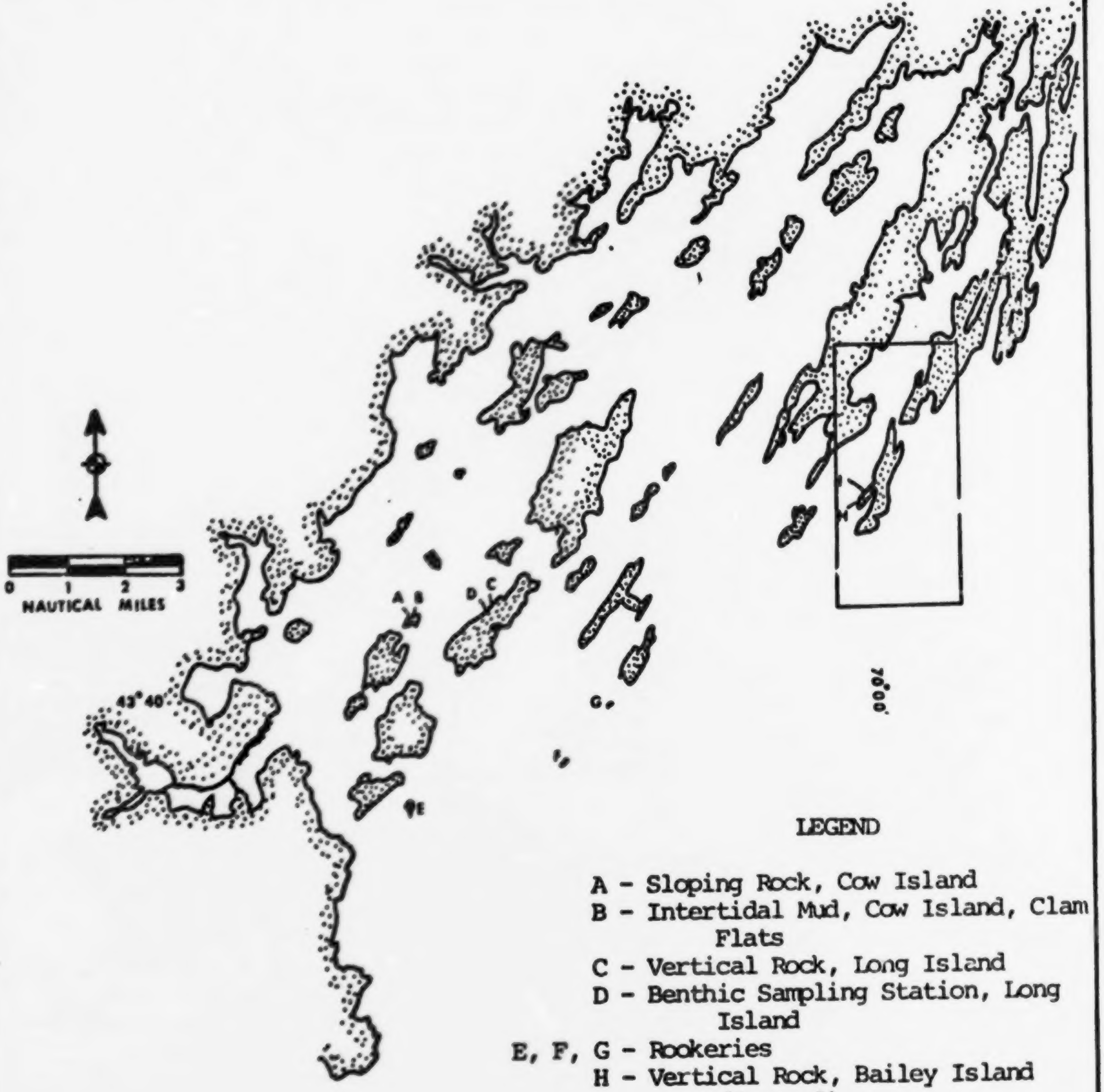
(1) The oiled stations and control (unoiled) stations used in the three earlier surveys were again evaluated and compared with respect to diversity and density of organisms, including both plant and animal communities. Station locations are shown in Figure 1. As shown, the oily stations are in the southwest portion of Casco Bay, whereas the control stations are toward the northeastern portion of the Bay. The purpose of this comparison for this current survey was to determine whether or not variations found in cleaned areas of rocks, beaches or in cropped algae zones could be attributed to natural seasonal variations or to the effects of cleaning. Longer-term effects of the oil spill on the intertidal ecosystems in Casco Bay were also ascertained by this technique.

(2) Diversity and density of organisms between cleaned and uncleaned areas both within and between oiled and control stations were studied to establish the effectiveness of cleaning operations on re-settlement. The sample areas were further subdivided into vertical rock stations and sloping rock stations because while these areas have similar species, the areal distribution of plants and animals is different and they are also subject to different physical forces within the environment.

(3) Intertidal sampling stations were divided into two zones: (a) the upper tidal zone, which visually had been most heavily impacted by the spilled oil, and (b) the lower tidal zone, which had also been impacted by oil but apparently to a lesser degree.

FIGURE 1

CASCO BAY
Location of the Accident (I). The Tamano at Anchor (II),



LEGEND

A - Sloping Rock, Cow Island
B - Intertidal Mud, Cow Island, Clam Flats
C - Vertical Rock, Long Island
D - Benthic Sampling Station, Long Island
E, F, G - Rookeries
H - Vertical Rock, Bailey Island (Control)
I - Sloping Rock, Bailey Island (Control)
K - Clam Flat, Beals Cove, Orrs Island (Control)
W - Mid-Bay Water
X - West Beach

(4) Effectiveness of beach removal operations was evaluated by visual inspection of cleaned beach with respect to the apparent physical condition of the beach. Sediment samples were collected from three depths at a cleared beach and analyzed for oil content. Other samples were collected from a non-cleared area of the same beach.

(5) Longer-term effects of the oil spill on intertidal soft-shell clam populations were evaluated by determining the length frequency distribution of the clams during this survey, and comparing the results with the results obtained during Survey III (November, 1972).

Field Methods:

a. Intertidal Rocky Stations - On each intertidal rock station, on Cow Island (A) and Bailey Island (I) [See Figure 1], counts of the organisms were made using 10 x 10 cm grids, three on the lower tidal zone and three on the upper tidal zone. After counting, the organisms within each grid were scraped from the rock and taken to the laboratory for closer inspection and identification. Strips that had been cleared at each station during the July 1972, survey were sampled similarly.

b. Beaches - Beach sands were collected in clean glass bottles from two depths at three different stations on West Beach, Long Island (X). All these samples were taken from the lower mid-beach; two were taken within the area where oily sand was removed and one taken outside of this area. These were returned to TRC for analysis of oil content. In addition, samples were taken at three depths: 0 - 10 cm, 20 - 30 cm, and 30 - 40 cm at one station in the area that had been cleaned.

c. Clam Flats - Intertidal clam flats at Cow Island (B) were sampled by collecting three sediment samples, 25 x 30 x 35 cm volume each. Three similar samples were collected at the control station at Beals Cove, Orr Island (K). The samples were sifted through 1 mm mesh screens. The soft-shell clam, Mya arenaria, was separated out, counted and measured along the hinge line.

Laboratory Methods:

Biological samples were frozen upon returning from the field to prevent decay. Each grid sample was sorted and speciated under a dissecting microscope. Numbers of species and numbers of individuals of each species were enumerated for each of the intertidal rock stations. Wet weight of seaweed (macroalgae) was measured for Fucus or Ascophyllum collected in the grid samples.

Beach sediments were extracted at our operating base in Casco Bay immediately upon return from the field. Twenty-five ml of carbon tetrachloride were added to approximately 100 grams wet weight of sediment and stirred for one minute with a glass rod. The CCl_4 and extracted oil was decanted into a 100 ml volumetric flask and the washing process repeated with three more 25 ml CCl_4 extractions. The extractions were taken to TRC's Chemistry Laboratory for infrared analysis.

Upon receipt of these extracts in our Chemistry Laboratory, they were passed through one-inch of anhydrous sodium sulfate to remove traces of water. The sodium sulfate was then flushed with carbon tetrachloride to wash all the oil through. The extracts were then placed in 100 ml volumetric flasks and diluted to volume with Spectrograde carbon tetrachloride. A solvent blank was carried through the same field extraction and laboratory procedure as the samples. A portion of each extract was then scanned in the range of 4000 cm^{-1} to 2400 cm^{-1} on a Perkin-Elmer Model 727 Infrared Spectrophotometer with spectrograde carbon tetrachloride in the reference beam. The cells employed were standard matched silica cells and, depending on the concentration of oil in the sample, the pathlength used was either 1 cm or 5 cm.

In order to quantify results, a sample of the Number 6 Fuel Oil obtained from the TAMANO was weighed and diluted to volume with Spectrograde carbon tetrachloride. From this stock solution, a series of standards were prepared. The absorbance values from these standards were used to prepare a calibration curve. The concentration of oil in the samples was then read from this curve.

RESULTS

RECOVERY AND GENERAL CONDITION OF INTERTIDAL POPULATIONS

I Uncleaned Rocks

As indicated previously, investigations of species diversity and population density were carried out in oiled and control stations on both vertical and sloping rocks in the intertidal zone. The results and discussion for vertical and sloping rocks are presented separately below.

Sloping Rock Stations - General Observations

A substantial difference in species diversity and abundance is found between the oiled (Cow Island) and control (Bailey Island) sloping rock stations. Table 1 shows that nearly twice as many species are present at the control as at the oiled station; twenty species are present at Bailey Island, as opposed to twelve at Cow Island. It is in the lower tidal zone (see Table 2). Some of those species absent at Cow Island are crustaceans -- two species of mites (Halacaridae), copepods and an unidentified crustacean larva. One species of amphipod, Hyale prevostii, is present at Cow Island but at a very low density compared to Bailey Island. Total numbers of barnacles (Balanus balanoides) are comparable for both stations, although densities by zone differ between stations.

Roundworms (Nematoda) and flatworms (Platyhelminthes) present at Bailey Island are not found at Cow Island. Although a polychaetous species (an annelid worm) living in association with Balanus balanoides is present at both control and oiled stations, the density is lower at the oiled station.

Three species of periwinkles (Littorina) are among the dominant organisms at both Bailey and Cow Island but vary in their proportional numbers at these stations. Littorina littorea is sparsely represented at both stations, although in somewhat denser numbers at Cow Island. Littorina obtusata is more abundant at the control than at the oiled station. Littorina saxatilis, however, is considerably more abundant at Cow Island. This is true also for Skenea planorbis, another gastropod, and for an isopod which is about twice as abundant at the oiled station.

Dog whelks are more abundant at Bailey Island than at Cow Island, with no egg cases of the species being present at the oiled station. Mussels present at Bailey Island outnumber those at Cow Island. A moderately abundant hydroid found on the rocks and macroalgae at Bailey Island is absent at Cow Island.

Table 3 shows comparable wet weights for macroalgae taken from the randomly selected sloping rock stations on Cow Island and Bailey Island. However, the visual observations indicate that the algal growth on both islands is more luxuriant than suggested by the table.

Sloping Rock Stations - Discussion of Results

Laboratory analyses reveal that the dominant species at Cow Island have not recovered from the impact of the oil spill. At the oiled and control stations, barnacles and blue mussels (Mytilus) have exchanged ranks since Survey III to first and second place, respectively. The control station has about twice as many barnacles in the upper tidal zone as in the lower tidal zone, whereas at the oiled station, the converse is true. Furthermore, mortality of barnacles in the upper tidal zone at Cow Island is more than twice as great as mortality in the comparable zone at Bailey Island. This is supported by field observations. Figure 2 shows one representative area of the upper littoral zone at the oiled station where up to seventy per cent of the barnacles are dead. This includes some mortality of this years set which died after settling on the oily rocks. In contrast, barnacles are abundant and healthy on the upper rock of the control station. On the lower rock of this control station, barnacle mortality is approximately twice as great as that on the lower rock at Cow Island. This difference can most probably be attributed to grazing by the dog whelks (Thais lapillus), which is abundant in this zone at the control station. Clusters of this organism grazing on barnacles can be seen in Figure 3. At Cow Island, numbers of this gastropod were much reduced. This may account for lower barnacle mortality in the lower tidal zone at Cow Island.

Recolonization of the rocks by rockweed (Fucus) is beginning, although slowly. Fronds of this macroalgae are approximately 2 - 3 cm in length and very sparsely scattered in most of the upper tidal zone. Settlement appears to occur in those crevices and areas where silt has accumulated. It is interesting that removal of the top layers of this sediment often reveals a mixture of unweathered oil and older sediment deposits. In the upper tidal zone of Cow Island (Figure 2), Fucus is sparse compared to the Fucus of the same zone at Bailey Island (Figure 4). In contrast, knotted wrack (Ascophyllum) and Fucus are as dense in the lower tidal zone at Cow Island (Figure 5) as those algae

TABLE 1

TOTAL NUMBER OF SPECIES AT INTERTIDAL ROCK STATIONS

Sloping Rock Stations		Vertical Rock Stations	
Cow Island (oiled)	12	Long Island (oiled)	10
Bailey Island (control)	20	Bailey Island (control)	13
Cow Island Cleaned Strip (oiled)	14	Long Island Cleaned Strip (oiled)	7
Bailey Island Cleaned Strip (control)	10	Bailey Island Cleaned Strip (control)	8

TABLE 2

NUMBER OF ORGANISMS AT THE SLOPING ROCK STATIONS PER 0.01 M^2

Species	Bailey Island (Control)			Cow Island (Oiled)		
	Survey III[*]	Lower Rock	Upper Rock	Survey III[*]	Lower Rock	Upper Rock
ANNELIDA						
Polychaeta commensal with Balanus		115				23
ARTHROPODA						
Amphipod Type A		1	5			
Hyale prevostii (Type B)		39	92			4
Mutilated amphipods		3				
Anurida maritima		27	14			2
Balanus balanoides	743	157	334	777	302	153
Copepoda		2				
Crustacean larva		2				
Halacaridae - red		1				
Isopoda Type A		2	2			8
MOLLUSCA						
Littorina littorea		2		1	1	8
Littorina obtusata	995	216	50	405	2	39
Littorina saxatilis	138	3		223	9	11
Mytilus edulis	879	293	34	912	17	32
Mytilus spat[a]		abundant			sparse	moderate
Skenea planorbis	.21	1		164	11	
Tellina agilis		2				
Thais egg cases[a]		18	5			
Thais lapillus	8	12	1		1	
NEMATODA		39				
PLATYHELMINTHES		2				
TOTAL FAUNAL NUMBERS	2784	919	532	2482	343	280

[*] Values taken from Casco Bay I report.

[a] Not included in total faunal numbers.

TABLE 3

WET WEIGHT IN GRAMS OF ALGAE IN CONTROL AND OILED STATIONS PER 100 CM^2

Zone	Station	Survey I July 1972	 II September 1972	 III November 1972	 IV August 1973
Sloping Rock					
High Rock	Bailey Island (Control)	187	80	89	97
	Cow Island (Oiled)	32	68	36	81
Low Rock	Bailey Island (Control)	803	1888	551	78
	Cow Island (Oiled)	44	223	248	--
Vertical Rock					
High Rock	Bailey Island (Control)	31	28	24	10
	Long Island (Oiled)	0	20	21	10
Low Rock	Bailey Island (Control)	33	168	191	260
	Long Island (Oiled)	37	41	62	44

FIGURE 2:

Upper Tidal Zone at Cow Island - Up to 70% of Barnacles l

FIGURE 3:

Lower Tidal Zone at Bailey Island Sloping Rock Showing Dog Whelks Grazing on Barnacles

FIGURE 4:

Upper Tidal Zone at Bailey Island Sloping Rock Showing Dense *Fucus*

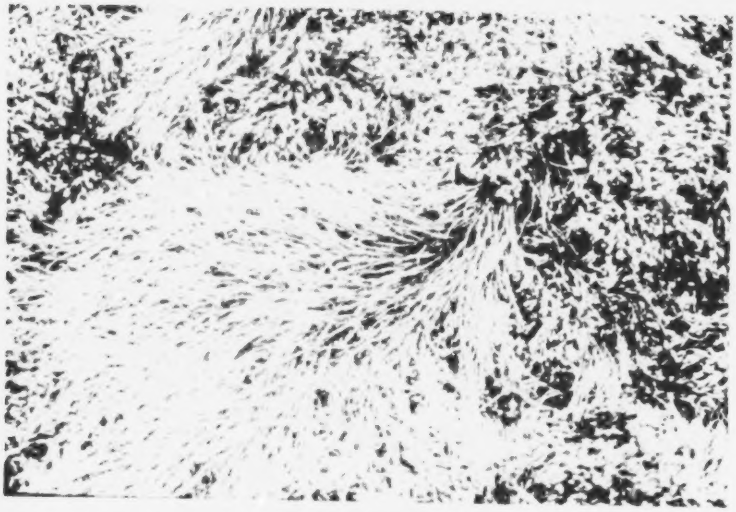


FIGURE 5:

Cow Island - Brown Algae Zone

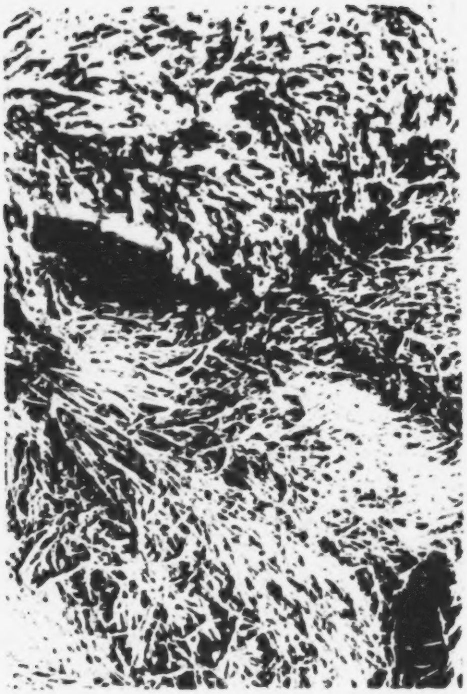


FIGURE 6:

Bailey Island - Brown Algae Zone

in the same zone at Bailey Island (Figure 6). The seaweed at both stations is lush and healthy. It would appear that where seaweed was killed off by the oil, such as in the upper tidal zone at Cow Island, recolonization is slowly occurring. Where the initial impact of the oil was not as great, such as in the lower tidal or *Ascophyllum* zone, recovery of the seaweed has been complete.

An important finding of Survey IV is the presence of amphipods at the oiled station for the first time during any survey. One species of amphipod is present at Cow Island, although at much fewer numbers than at Bailey Island. Equally important as the presence of amphipods at the oiled station is a reduction in the diversity of amphipod species at the control station since last year. This may reflect a natural fluctuation in the population. It is interesting to note, however, that the same species, *Hyale prevostii*, is dominant at both control and oiled stations this year. A second species is also found at the control station. Blumer et al (1971), Sanders et al (1972), and Baker (1971) have shown that amphipods are indicator organisms for oil pollution. These animals are widely distributed and are one of the most resistant groups of organisms to adverse changes in the environment (Kunkel 1918). The susceptibility to oil may be due to its particular niche and morphology which makes avoidance of the oil nearly impossible. One might conclude that the other species of crustacea lacking at Cow Island -- mites, copepods, and crustacean larvae -- are similar to amphipods in their exposure and vulnerability to oil. In contrast, knotted wrack (*Ascophyllum*) and *Fucus* are as dense in the lower tidal zone at Cow Island (Figure 5) as those algae in the same zone at Bailey Island (Figure 6). The seaweed at both stations is lush and healthy. It would appear that where seaweed was killed off by the oil, such as in the upper tidal zone at Cow Island, recolonization is slowly occurring. Where the initial impact of the oil was not as great, such as in the lower tidal zone or *Ascophyllum* zone, recovery of the seaweed has been complete.

Distributions of the periwinkles, *Littorina obtusata* and *Littorina saxatilis* differ considerably at the control and oiled stations (see Table 2). An increase in the proportional numbers of *L. saxatilis* to *L. obtusata* is evident at the oiled station, while the abundance of *L. obtusata* far exceeds that of *L. saxatilis* at the control station. This difference might be due to varying degrees of resistance to oil by the two species. *L. saxatilis* is a relatively hardy species which can live in the spray zone of the rocks. Due to a gill cavity which functions as a sort of "lung", this animal needs only to be submerged at every spring tide, or every 31 days (Carson 1955). Possibly, this periwinkle was able to live and feed in the high splash zone or tidal pools during the initial period of heavy oiling, thus escaping the oil. Another advantage of *L. saxatilis* is its reproductive habits. Eggs and young are held within the female while they develop. L. obtusata, on the other hand, lays its eggs on the seaweed fronds, where the young stages are more exposed to any alterations in the environment. During low tide, adults of this animal seek protection from dessication in the moist seaweed fronds (Zottoli 1973). This niche requirement then would make L. obtusata vulnerable to contact with the oil. The increased numbers of L. saxatilis at Cow Island may mean that competition for this hardier periwinkle has been reduced with fewer numbers of L. obtusata. Thus, L. saxatilis has been able to invade those zones normally dominated by L. obtusata.

Vertical Rock Stations - General Observations

For the most part, the vertical rock stations at Long Island (oiled) and Bailey Island (control) are similar in their species composition (see Table 1) and total abundance of organisms (see Table 4). Bailey Island has a slightly greater diversity and abundance than Long Island. At both stations; barnacles, periwinkles, blue mussels, rockweed and knotted wrack are dominant. However, two species which are quite abundant at the control station -- amphipods and hydroids -- are absent at the oiled station. Mites and colonial tunicates, two less common species found at the control station are also absent from the oiled station.

Following the trend of the sloping rock stations, the distribution of Littorina is substantially different at the control and oiled sheer rock stations. Numbers of L. obtusata are much reduced at Long Island in comparison to Bailey Island, whereas L. saxatilis is abundant at Long Island and absent from Bailey Island.

Fucus recolonization is occurring only sparsely in the most heavily oiled zone. Although Table 3 shows wet weights of macroalgae to be sparse but comparable in the upper tidal zones of both stations, in reality Fucus is somewhat more abundant at the control than at the oiled station. On the lower rocks, Ascophyllum is more abundant at the control than at the oiled station; therefore, wet weights shown in Table 3 for this zone are representative of the stations.

At Long Island, recolonization of barnacles has been good on the lower rocks. Littorina littorea which was missing after Survey II (VAST/TRC, 1973) is back in plentiful numbers. Amphipods, absent at Long Island during all surveys, are still missing from this station. However, in contrast to previous surveys, Hyale prevostii is present at the control station.

TABLE 4

NUMBER OF ORGANISMS PER .01 M^2

Species	Vertical Rock Stations			
	Bailey Island (Control)		Long Island (Oiled)	
	Lower Rock	Upper Rock	Lower Rock	Upper Rock
ANNELIDA				
Polychaeta, mutilated		1	1	
ARTHROPODA				
Amphipod Type B	12			
(*Hyale prevostii*)				
Anurida maritima	4			
Balanus balanoides	52	694	209	502
Halacaridae - red	2			
Isopoda Type A	5		2	
CHORDATA				
Tunicate - colonial	4			
COELENTERATA				
Hydroid - Branched colonies	abundant			
MOLLUSCA				
Littorina littorea	1	24	1	88
Littorina obtusata	69	232	18	2
Littorina saxatilis			32	34
Mytilus edulis	82	41	82	50
Mytilus spat	abundant		moderate	sparse
Skenea planorbis	13	2	4	5
NEMATODA				
TOTAL	244	994	350	681

FIGURE 7:

Long Island - Upper Rocks Adjacent to Sampling Station

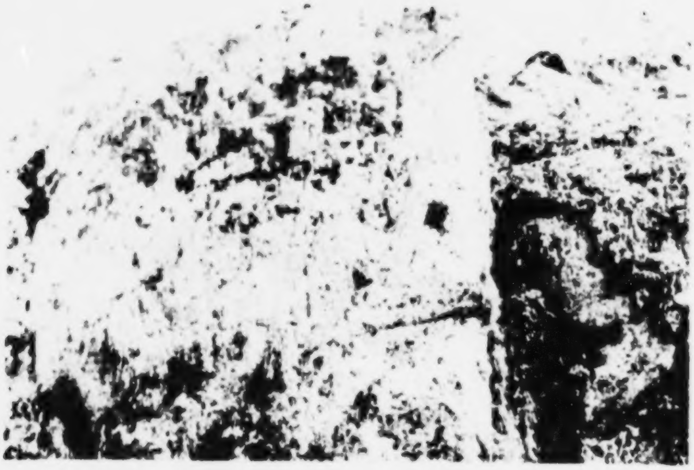


FIGURE 8:

Long Island - Cleared Strip (Center) Showing This Year's Barnacle Set

FIGURE 9:

Bailey Island Vertical Rock - Mid and Lower Tidal Zones

FIGURE 10:

Long Island Cleared Strip, Right Side
Uncleared Strip, Left Side

Vertical Rock Stations - Discussion of Results

Recovery of the intertidal community at Long Island has been good, except in the most heavily oiled zone. As at Cow Island (see Figure 2), some areas of upper rock at Long Island adjacent to the sampling station are fairly bare (see Figure 7). Where this year's set of Balanus has settled on oil, the animals have died. A comparison of the oiled to the control stations may be seen in the top left portion of Figure 8 and Figure 9, respectively. Field observations, as well as quantitative counts, show that the control station supports a denser barnacle population than the oiled station. Fucus and Ascophyllum, although present at both stations, are more abundant at the control station. The recovery of both these species in the high zone at Long Island is shown in Figure 10.

At the oiled station, a relatively low density of Ascophyllum is correlated with high Balanus density, whereas at the control station the converse is true. Rocks in the lower zone where Ascophyllum had died have been recolonized by Balanus. Since recolonization of macro-algae takes longer than barnacle resettlement, it will take more than a year's time to see if Fucus and Ascophyllum regain their normal abundance in the areas contaminated with oil.

A definite change in species distribution is found in the populations of Littorina at Long Island. The rank order of the four dominant species: Balanus balanoides, Littorina obtusata, Mytilus edulis, and Littorina saxatilis, which remained the same over three surveys, has changed at the oiled station by Survey IV (see Table 5). L. saxatilis rises from fourth to third in rank, while L. obtusata, which had been second in rank falls to fourth place. In actuality, L. littorea becomes fourth in rank, since it is more abundant than L. obtusata. At the control station, the rank order remains constant over all four surveys. This change in Littorina distribution is even more pronounced at Long Island than at Cow Island, but this trend is the same at both. L. saxatilis has become the exploiter organism in an environment where the oil has stressed L. obtusata, a less tolerant species, which occupies a similar niche.

The absence of amphipods at Long Island supports the argument discussed above that these organisms are sensitive to oil. In addition a decline in the diversity of these organisms at Bailey Island (control) from four species to one species is further evidence that the control stations became contaminated with oil (VAST/TRC, 1973). The absence of hydroids at both Long Island and Cow Island may indicate that these organisms are also sensitive to oil.

II Recolonization Studies

Part of the initial Casco Bay study (VAST/TRC, 1973) looked at the recolonization of organisms in control and oiled rock stations. There were two rock types: sloping (Cow Island) and vertical (Long Island). Controls for each of these areas were on Bailey Island. During Survey I (July 1972), strips (1.5 ft wide running from high to low tide levels) in each of the test areas, oiled and control, were scraped clean of organisms. Recolonization of these areas was checked during this and the two previous surveys (II and III). As in the previous surveys, recruitment and population ratios were again used. These ratios are a method used to establish the degree of recolonization and they are based on the following assumptions:

- ° The control stations have remained oil-free.
- ° The pool of organisms available for recolonization came from areas adjacent to the cleared strips.
- ° Recolonization of the control areas reflects the natural processes.

The recruitment ratio was formed by comparing the number of animals, regardless of species, on bared areas at the control stations to the number on the bared areas at the oiled stations (see Table 6). For example, during this survey there were 373 animals at the control areas (Bailey Island) and 480 animals on the oiled area (Cow Island). The recruitment ratio, R, is thus expressed by:

$$R = 373/480 = 0.8.$$

The population ratio is based on species common to the control and oiled areas. It is formed by comparing the number of animals in the area adjacent to the control clear strip to the numbers adjacent to the oiled cleared strip. Data for this ratio comes from Tables 2 and 4. For example, in August 1973 at sloping rock, there were 1394 animals/ $0.01\ m^2$ available for recolonization at the control station (Bailey Island) and 623 animals/$0.01\ m^2$ available at the oiled station (Cow Island). The population ratio is:

1394/623 = 2.2.

The population ratio is a "weighting factor" to account for differences in abundance between the two areas. Whenever the recruitment ratio exceeds the population ratio, more animals than would be expected by sheer differences in population sizes were moving onto the bared areas at the control station than onto a similar area at the oiled locations.

Vertical Rock Stations

Table 6 shows that the population ratio exceeds its recruitment ratio at the vertical rock stations. This means that the recruitment ratio on the bared areas at the control stations has decreased since Survey III. (This may be due to oil spreading into the control regions.) It also suggests that recruitment at the Long Island oiled stations has increased during this time. By Survey IV, however, the barnacles, *Balanus*, *Mytilus*, and *Fucus* -- those organisms spending early life in the plankton -- had settled on the vertical rock. The comparison of recruitment and population ratios shows that rock scraping does improve the substrate for sessile organisms. This is supported by field observations: cleared areas of rock at Long Island appear to be improved over uncleared areas (see Figure 11). The apparent inhibition of barnacle settlement in the lower tidal area is consistent with the usual tendency of these animals to inhabit specific zones. Barnacles do not normally dominate in the brown algae zone since they are not best adapted to this niche. The question therefore arises as to why barnacle settlement occurs at all levels of the cleared strip at Long Island (the oiled) but not at the lower zone at the control area. On the oiled stations, the abundance of individuals is about the same at both cleared and uncleared areas. In oiled stations, the total abundance is equivalent to that found on the uncleared areas of the control station (Tables 4 and 7).

It is important to realize that scraping the rocks introduces a stress to the rock communities. This stress is reflected in the fact that there were fewer species and individuals of this one-year community on the cleared strips at the control stations than on the uncleared stations (Tables 1, 4, and 7). This implies that these communities on the cleared strips have not yet reached natural equilibrium. At the oiled stations, although total numbers of individuals on the cleared strips are comparable to the totals on uncleared strips, the lower diversity of species of the cleared strip as compared to the uncleared strip indicates that here, too, natural equilibrium of the cleared strip community has not been reached.

TABLE 5

TOTAL NUMBERS AND RANK ORDER OF DOMINANT SPECIES

Species	Station	Survey				Rank Order			
		I	II	III	IV				
		July 1972	September 1972 per .01 m^2	November 1972	August 1973 per .01 m^2	I	II	III	IV
Balanus balanoides	Long Island (Oiled)	1036	1425	1014	717	1	1	1	1
	Bailey Island (Control)	1730	1631	1400	746	1	1	1	1
Mytilus edulis	Long Island (Oiled)	58	25	140	132	3	3	3	2
	Bailey Island (Control)	678	498	563	123	3	2	3	3
Littorina obtusata	Long Island (Oiled)	210	137	215	20	2	2	2	4*
	Bailey Island (Control)	1059	418	564	301	2	3	2	2
Littorina saxatilis	Long Island (Oiled)	28	7	44	66	4	4	4	3
	Bailey Island (Control)	35	5	13	0	4	4	4	4

*Littorina littorea.

TABLE 6

RECOLONIZATION OF CLEARED STRIPS OF INTERTIDAL ROCK STATIONS

	Survey					
	II September 1972 Total Number Of Individuals		III November 1972 Total Number Of Individuals		IV August 1973 Number Of Individuals Per .01 M^2	
	Oiled	Control	Oiled	Control	Oiled	Control
Sloping Rock						
High Zone	41	396	286	367	208	392
Low Zone	156	805	572	946	680	324
Total	197	1201	858	1313	888	716
Recruitment Ratio	6.1		1.5		0.8	
Population Ratio	2.2		1.1		2.2	
Vertical Rock						
High Zone	10	215	113	484	513	553
Low Zone	188	148	51	91	337	7
Total	198	363	164	575	850	560
Recruitment Ratio	1.8		3.5		0.7	
Population Ratio	1.6		1.8		1.3	

FIGURE 11:

Bailey Island Cleared Strip,
Right Third of Picture

Sloping Rock Stations

The results of quantitative sampling indicate that the cleared strip at Cow Island has a greater species diversity than the uncleared adjacent areas (see Tables 1, 2, and 8). At Bailey Island, the cleared strip supports a lower abundance of animals than the cleared strip at Cow Island. The population ratio (see Table 6) is two and one-half times greater than the recruitment ratio. Recruitment on Bailey Island (control) has markedly decreased and this may be due to encroaching oil into the control areas. The greater recruitment at Cow Island is due primarily to large numbers of barnacles, periwinkles, mussels, and algae. In addition, a significant finding is the presence of two species of amphipods.

One factor that would contribute to the abundance of barnacles at the cleared strip on Cow Island is the absence of its major predator, the dog whelk. The greater numbers of the periwinkle *Littorina saxatilis* may be attributed to the fact that this animal is invading the niche normally occupied by *L. obtusata*; a pattern similar to the adjacent uncleared areas of Cow Island. These shifts in populations would indicate that as at the vertical rock stations, the communities on the cleared strips have not yet reached a state of equilibrium. For instance, at each station re-establishment of macroalgae takes more than a year. Barnacles have recolonized cleared strips in what is obviously the brown algae zone (see Figure 12). Field observations ascertained that populations of algae and marine organisms in tidal pools in the clean rock areas are much more diverse than those in tide pools in adjacent areas that had not been cleaned.

EFFECTIVENESS OF CLEAN-UP PROCEDURES

Following the TAMANO oil spill, three separate procedures were employed to clean-up the oil. These were:

- Cleaning rocks with pressurized hot water,
- Cropping seaweed, and
- Removal of oiled beach sand.

TABLE 7

CLEARED STRIPS AT INTERTIDAL ROCK STATIONS

NUMBER OF ORGANISMS PER .01 M^2

Species	Vertical Rock Stations			
	Bailey Island (Control)		Long Island (Oiled)	
	Lower Rock	Upper Rock	Lower Rock	Upper Rock
ALGAE				
Fucus Holdfasts			3	
ANNELIDA				
Polychaeta commensal with *Balanus*				
ARTHROPODA				
Amphipod Type A				
Hyale prevostii Type B				
Amphipod unknown				
Anurida maritima				
Balanus balanoides	2	388	273	418
Crustacean larva				
Halacaridae - black				
Halacaridae - Red				
MOLLUSCA				
Littorina littorea		2	5	86
Littorina obtusata		152	18	1
Littorina saxatilis	5	8	29	8
Mytilus edulis		3	8	
Mytilus spat[*]	sparse	sparse	sparse	sparse
Skenea planorbis				
Tellina agilis				
Thais lapillus			1	
NEMATODA				
NEMERTEA				
TOTAL FAUNAL NUMBERS	7	553	337	513

[*] Not included in total faunal numbers.

TABLE 8

CLEARED STRIPS AT INTERTIDAL ROCK STATIONS

NUMBER OF ORGANISMS PER .01 M^2

Species	Sloping Rock Stations			
	Bailey Island (Control)		Cow Island (Oiled)	
	Lower Rock	Upper Rock	Lower Rock	Upper Rock
ALGAE				
Fucus Holdfasts	1	38	14	56
ANNELIDA				
Polychaeta commensal with Balanus				
ARTHROPODA				
Amphipod Type A		1		
Hyale prevostii Type B				
Amphipod unknown				
Anurida maritima	3	18		
Balanus balanoides	140	274	499	176
Crustacean larva				
Malacaridae - black			2	
Malacaridae - red				
MOLLUSCA				
Littorina littorea	6		5	2
Littorina obtusata	89	58	20	5
Littorina saxatilis	15		53	7
Mytilus edulis	68	3	82	41
Mytilus spat*	abundant	spars	abundant	sparse
Skenea planorbis				
Tellina agilis			1	
Thais lapillus	1			
NEMATODA			4	
NEMERTEA				1
TOTAL FAUNAL NUMBERS	324	392	680	288

* Not included in total faunal numbers.

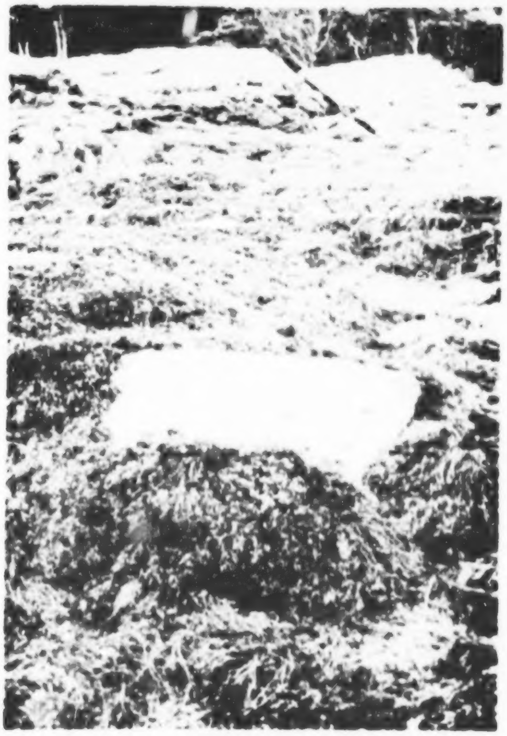


FIGURE 12:

Cow Island Cleared Strip
Lower Mid Zone

FIGURE 13:

Long Island - Pressurized Hot Water Cleaned Rocks in Lower Tidal Zone

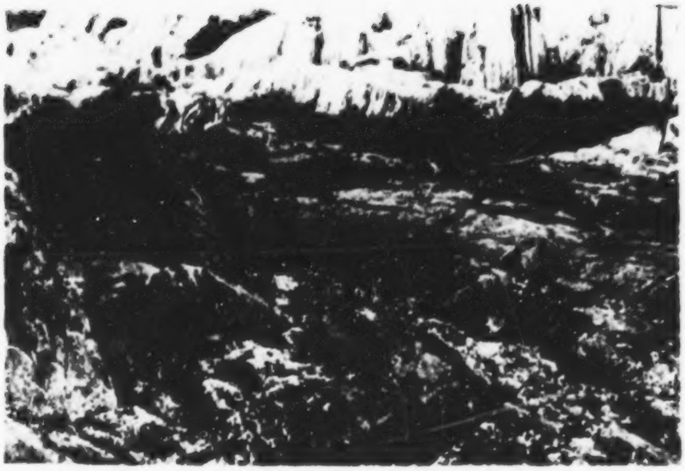


FIGURE 14:

Long Island - Pressurized Hot Water Cleaned Rocks in Upper Tidal Zone

TABLE 9

LONG ISLAND ROCKS - CLEANED BY HOT WATER

NUMBERS OF ORGANISMS PER 0.01 M^2

Species	Totals	
	Lower Rock	Upper Rock
ARTHROPODA		
Balanus balanoides	307	
Crustacean larva	1	
MOLLUSCA		
Littorina littorea	62	26
Littorina obtusata	1	
Littorina saxatilis	56	
Mytilus edulis	64	
TOTAL FAUNAL NUMBERS	496	26
MACROALGAE		
Fucus Holdfasts	1	

I Rock Cleaning With Pressurized Hot Water

Oil had coated the intertidal rocks near the ferry dock on Long Island, a public access area. The oil was removed by washing the rocks with pressurized hot water (800 - 1100 psi, 150 - 170°F). We were able to estimate the biological impact of the method by comparing the intertidal populations in the washed areas to those in the unwashed oiled locations.

The barnacles (Balanus balanoides) and the molluscs best show the effects of washing. The upper rock zone near the dock appear to be devoid of all animals (see Figure 13). This is supported by data in Table 9. Similar rock zones in unwashed oiled areas on Long Island show a much greater abundance of animals (Table 4). Washing appears to retard recovery on the rocks. However, there are other factors, such as public traffic and the effects of washing pressures and temperatures. Determination of the effects of these factors is beyond the scope of this report.

In the lower rock zone, rock washing appears to have a beneficial effect (Figure 14). The barnacle and mollusc populations are much more abundant in the washed area than in the unwashed locations (Tables 4 and 9). Field observations ascertained that populations of algae and marine organisms in tidal pools in the washed rock areas are much more diverse than those in the tidal pools in adjacent areas that had not been cleaned.

II Effects of Seaweed Cropping on Cow Island

Following the TAMANO spill, oil-soaked macroalgae on the northwest point of Cow Island and other areas were cut and removed as a clean-up measure in order to decrease the amount of oil leaching back into the environment. Field observations of that area one year later indicate that cropping the algae has markedly reduced its re-population of the area. Comparison of this point (Figure 15) with the uncropped oiled sampling station at Cow Island (Figure 12) shows that the macroalgae which is left uncropped is rid of the oil and growing luxuriantly, whereas it is patchy and stunted in the cropped area (Figure 16). The sampling data indicated that the animal populations of the cropped area, although much less abundant, include nearly the same diversity of species as the cleared areas on Cow Island (Tables 8 and 10). An exception to this similarity with the uncropped station is the presence of abundant numbers of a sabellid polychaete. This tubiculous worm may be an indicator species which has invaded the rocks due to the presence of oil and the unstable condition of the intertidal environment. It would, therefore, seem that while cropping the algae does indeed help rid the area of oil, as reflected in the diversity of species recolonizing, cropping greatly reduces algal cover of the area. In each case, including the stations on Cow Island and Long Island, the algae seems to be the late successional species or the slowest to recolonize. Since its cover forms an important niche for intertidal organisms, it would be advisable in future clean-up operations to continue to crop only limited areas which are most heavily saturated with oil or don't crop at all.

III Effectiveness of Beach Sand Removal

West Beach on Long Island appears clean to the eye one year following the oil spill (see Figure 17). Based on visual observations, it seems to have recovered to its normal slope, bearing strength and grain size. Closer examination of the sand revealed some oil to be present, especially in the top layer of coarser stones. This is verified by quantitative IR analysis of samples taken from three areas along the beach (listed below). The samples (A, B) were taken from the section of beach from which oily sand had been removed in clean-up operations. A third sample (C) was taken from an area of the same beach that was not obviously contaminated by oil.

The analytical results for field extraction of beach sediments were:

Sample Identification	Mg Oil/100 Grams of Sample
Station A, surface to 10 cm depth	6.8
Station A, 20 to 30 cm depth	4.7
Station B, surface to 10 cm depth	4.4
Station C, surface to 10 cm depth	3.2
Station C, 20 to 30 cm depth	0.11
Station C, 30 to 40 cm depth	0.08

To measure the effectiveness of extraction by carbon tetrachloride, an additional test was performed. The aim of this test was to determine if all the oil contamination could be removed from sediments by the recommended carbon tetrachloride procedure. Several samples of sediment were analyzed from West Beach, Long Island, Casco Bay.

FIGURE 15:

Cow Island - Point Where Seaweed Was Cropped

FIGURE 16:

Cow Island - Cropped *Ascophyllum*

TABLE 10

AREAS OF CROPPED ALGAE - COW ISLAND

TOTAL NUMBERS OF ORGANISMS PER 0.01 M^2

Species	Totals
ANNELIDA	
Polychaeta commensal with Balanus	2
Polychaeta - tubiculous	18
ARTHROPODA	
Balanus balanoides	228
Isopoda Type A	1
MOLLUSCA	
Littorina littorea	1
Littorina saxatilis	8
Mytilus edulis	MODERATE
Skenea planorbis	4
Thais lapillus	1
MACROALGAE	
Ascophyllum nodosum	72 grams
Fucus sp.	> 4 grams
TOTAL NUMBER ORGANISMS	311

A 100 gram sample of each sediment material was treated with individual portions of carbon tetrachloride of spectrograde quality. Eight to ten such treatments were required before infrared spectroscopic analysis indicated an absence of oil in the last 25 ml extract. To ensure a complete removal of all oil contamination, the sediments were treated again with carbon tetrachloride in an eight-hour Soxhlet operation. The treated samples of sediment were then regarded as oil-free.

A stock solution of oil in carbon tetrachloride of known concentration was prepared with No. 6 oil taken from inboard the TAMANO. Measured amounts of this stock solution were added to each of the treated sediments. The amounts of oil added to these sediment samples were varied within a range of 0.4 - 14.6 mg of oil per 100 grams of sediment. This is the range of concentration found for the three sediment samples from the Casco Bay Survey reported above.

Each oil-spiked sediment sample was treated with four successive 25 ml portions of carbon tetrachloride. Approximately eight additional 25 ml aliquots of carbon tetrachloride were needed before infrared spectroscopic measurements failed to detect any No. 6 oil in the last carbon tetrachloride extract. Only 50% ± 10 of the oil contamination was removed to this point. The remaining oil required a Soxhlet extraction with carbon tetrachloride. The total amount of oil recovered was approximately 100% of the amount added to the sediment sample.

The small number of samples available for this test do not permit a statistical evaluation. However, the test data demonstrates the inadequacy of a carbon tetrachloride extraction for No. 6 oil from sediment at room temperature. Despite the numerous extractions with carbon tetrachloride, approximately one-half of the oil could not be removed from the sediments. When a Soxhlet treatment was employed, a complete recovery for the known amount of oil was obtained.

Consequently, for the extracts prepared in the field of samples of sediment materials from the Casco Bay survey area, the analytical results (reported above) appear to represent only approximately 50% of the oil actually present. The more likely concentrations are:

Sample Identification	Mg Oil/100 Grams of Sample
Station A, surface to 10 cm depth	12 - 14
Station A, 20 to 30 cm depth	9 - 10
Station B, surface to 10 cm depth	8 - 9

Sample Identification	Mg Oil/100 Grams of Sample
Station C, surface to 10 cm depth	6 - 7
Station C, 20 to 30 cm depth	∿ 1
Station C, 30 to 40 cm depth	∿ 1

Two specific recommendations appear to be in order. First, it is recommended that a more rigorous extraction method be incorporated into the analytical procedure, when it is applied to sediment materials. The Soxhlet extraction is apparently effective for a complete separation of oil from such samples. Secondly, it is recommended that the per cent recovery for oil be checked. This involves adding a given amount of oil to the sediment materials taken from each specific survey area. This second recommendation would establish the accuracy of the analytical data derived from the particular sample materials for each geographical area.

Results of the chemical analysis indicate that the clean-up operations removed most of the oil-soaked sand by comparison with concentrations last year. However, oil is still present in the cleared area of beach in greater concentrations than adjacent uncleared areas. This may be a result of a combination of factors: untreated sections of beach were less heavily contaminated initially, residual oil remained in the cleared portion, and littoral transport of oiled sands from other areas of the bay brought more oiled sediments onto the cleared area of West Beach. Beach cleaning may nevertheless be considered a valuable operation in that it prevents considerable amounts of oil from leaching into the marine environment.

EFFECTS OF TAMANO SPILL ON SOFT SHELL CLAM POPULATIONS

Length/frequency histograms for populations of Mya arenaria at Cow Island (oiled) and Beals Cove (control) are presented in Figure 21 for November 1972 and in Figure 18 for August of 1973. In both surveys, Mya are far more abundant at the control station (Beals Cove) than at the oiled station (Cow Island). The trimodal distribution at the control station probably represents a three-year population. Last year's set (1972) of 2 - 4 mm length young Mya (Figure 18) is probably the 10 - 28 mm length group this year (Figure 19). Equivalently, the 2 to 6 mm group that settled at Cow Island last year grew to 10 - 14 mm length this year. It is suggested, therefore, that a soft shell clam population can survive an oil impact such as occurred at Cow Island for at least a year and perhaps longer, as evidenced by the one large clam that survived to a 66 mm length. For some reason, the 35 - 56 mm

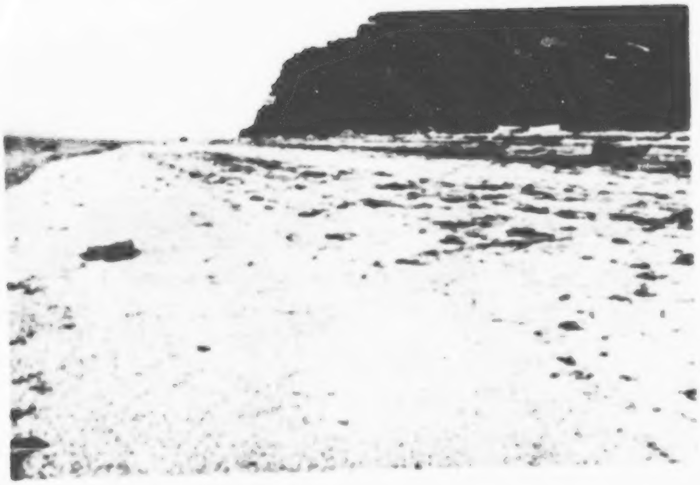
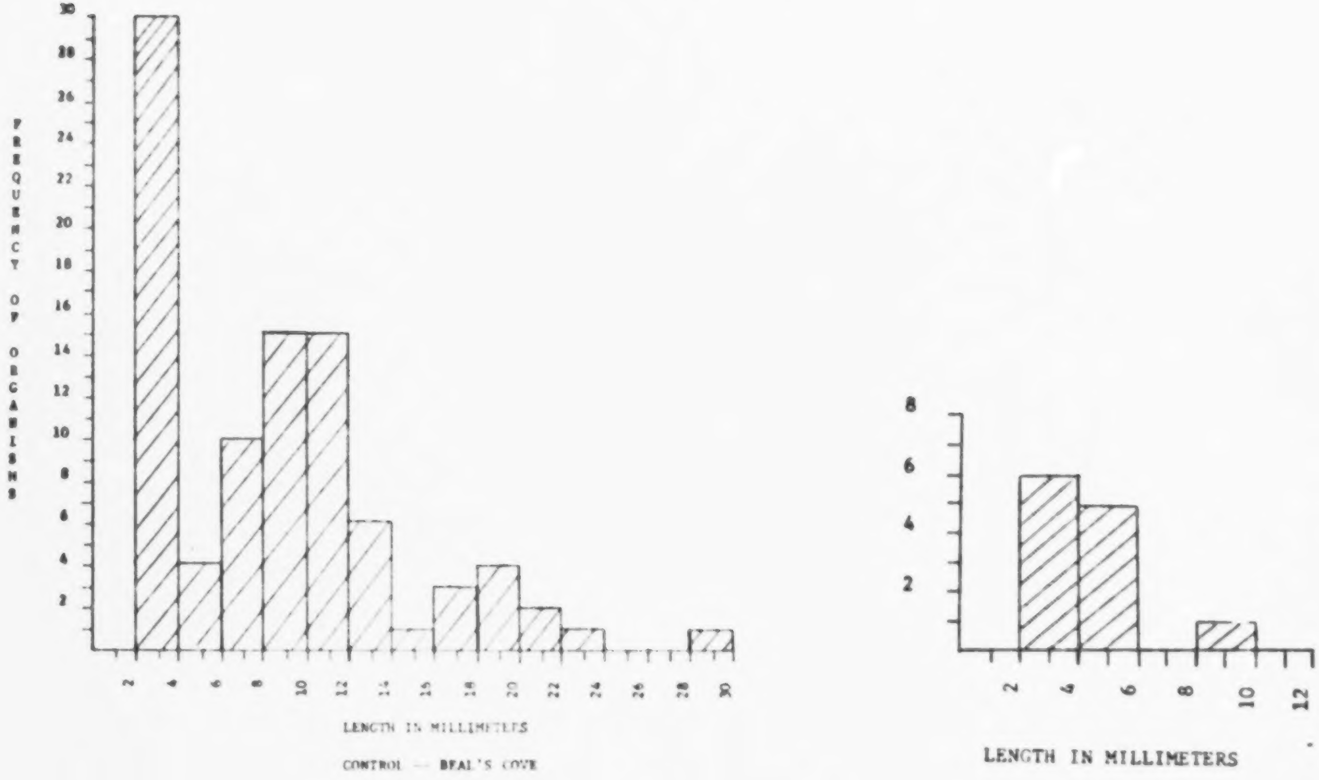


FIGURE 17:

Long Island - Cleaned Beach

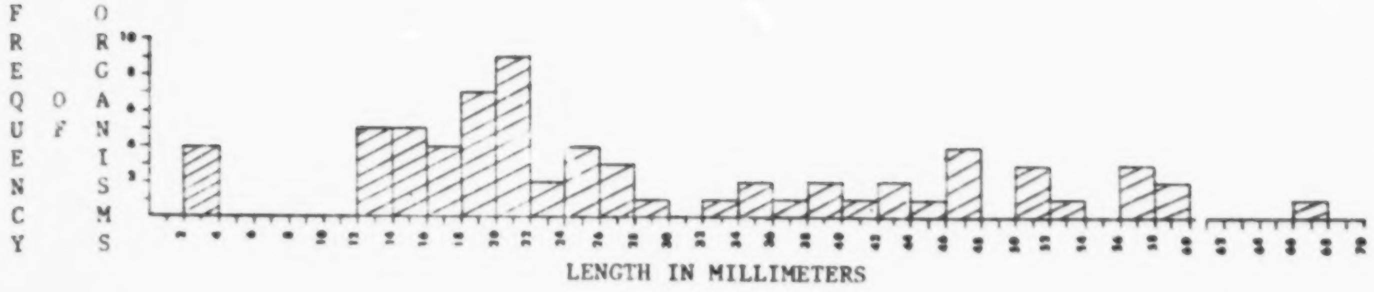


CONTROL -- BEAL'S COVE

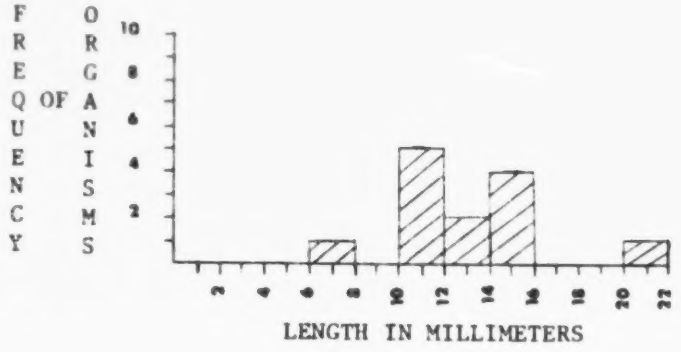
CONTAMINATED -- COW ISLAND

FIGURE 18:

Mya arenaria -- INTERTIDAL CLAM FLATS
SIZE/FREQUENCY DISTRIBUTION
(SURVEY III, NOVEMBER 1972)



CONTROL -- BEAL'S COVE



CONTAMINATED -- COW ISLAND

FIGURE 19:

Mya arenaria -- INTERTIDAL CLAM FLATS
SIZE/FREQUENCY DISTRIBUTION
(SURVEY IV, AUGUST 1973)

population present at Beals Cove this year is absent at Cow Island (Figure 18). This population was absent last year as well. Nor is there any indication of a new set this year at Cow Island that would correspond to the small 2 mm length clams present at Beals Cove. When contaminated by an oil spill, bivalves are known to retain the more toxic fractions of fuel oil (Blumer and Sass, 1972). It appears that the Tamano spill killed the year-old set at Cow Island last year, which resulted in little, if any, successful spawning and settlement this year. The small numbers of young present this year at Beals Cove may be a result of the accumulation of oil from more-or-less chronic releases into Casco Bay.

Since some young soft shell clams survived the initial impact, it appears that the clam population may be able to gradually re-establish itself.

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